DOCUMENT RESUME

ED 222 690 CE 034 073

TITLE	Automatic Data Processing, 4-1. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION	Army Ordnance Center and School, Aberdeen Proving Ground, Md.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	78
NOTE	166p.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01/PC07 Plus Postage.
DESCRIPTORS	Autoinstructional Aids; Behavioral Objectives; *Business Education; *Computer Literacy; *Computer Science Education; *Computer Storage Devices; *Data Processing; Data Processing Occupations; Digital Computers; High Schools; Individualized Instruction; *Input Output Devices; Learning Activities; Pacing; Postsecondary Education; Secondary Education; Textbooks
IDENTIFIERS	Military Curriculum Project

ABSTRACT

These two texts and student workbook for a secondary/postsecondary-level correspondence course in automatic data processing comprise one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. The purpose stated for the individualized, self-paced course is to provide general knowledge of punched card machines and automatic digital computers. It is intended for use as an introduction or sub-unit in computer programming or business and office practice courses. The course contains two lessons. The first, "Introduction to Punched Card Machines," contains four sections on general information and background, punched cards, punched card equipment, and basic considerations of report designing. The second lesson, "Introduction to Automatic Digital Computers," contains seven sections discussing classification of computers by use, computer arithmetic, functional elements of computers, classification of computers by generation, storage devices, and input-output devices. Appendixes cover references, computer arithmetic, and solutions to practical exercises. The student workbook contains review exercises and an exercise response list. Supplemental pamphlets contain the informative materials. A course examination is provided, but no answers are available. (YLB)

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MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL

Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
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THE NATIONAL CENTER FOR RESEARCH IN VOCATIONAL EDUCATION

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Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
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100 North First Street
Springfield, IL 62777
217/782-0759

NORTHWEST
William Daniels
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MIDWEST
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AUTOMATIC DATA PROCESSING

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Developed by:

United States Army

Development and Review Dates:

October 1973

Occupational Area:

Business and Office

Cost:

Print Pages:

188

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

None

Target Audience:

Grades 10-adult

Organization of Materials:

Two texts; student workbook with lesson objectives, assignments, exercises, and answers; course examination

Type of Instruction:

Individualized, self-paced

Type of Materials:			No. of Pages:	Average Completion Time:
Automatic Data Processing				
Lesson 1	–	Introduction to Punched Card Machines	43	Flexible
Lesson 2	–	Introduction to Automatic Digital Computers	79	Flexible
Student Workbook and Exercise Response List			17	
Examination			6	

Supplementary Materials Required:

None

Expires July 1, 1978

B

Course Description:

This course is designed to provide general knowledge of punched card machines and automatic digital computers. It contains two lessons.

Lesson 1 – *Introduction to Punched Card Machines* contains four sections. The introduction gives general information and background. The second section on the punched cards discusses the common characteristics, advantages, disadvantages, classifications, readings, and control punches of punched cards. The third section discusses general punched card equipment such as the card punch, interpreter, sorter, collator, reproducing punch, calculator, and accounting machine. The fourth section covers basic considerations of report designing.

Lesson 2 – *Introduction to Automatic Digital Computers* contains seven sections discussing classification of computers by use, computer arithmetic, functional elements of computers, classification of computers by generation, storage devices, and input-output devices. The appendices cover references, computer arithmetic, and solutions to practical exercises.

Each lesson contains objectives, readings, suggested study hints, review exercises and answers. The answers are programmed to provide immediate feedback. A correct answer is reinforced. An incorrect answer refers the student to further reading and the question is answered again until the correct answer is obtained. A course examination is provided, but no answers are available. This course was designed for student self-study and evaluation and can be used as an introduction or sub-unit in computer programming or business and office practice courses.

CORRESPONDENCE COURSE
of the
US ARMY ORDNANCE
CENTER AND SCHOOL

ORDNANCE SUBCOURSE NUMBER 905

AUTOMATIC DATA PROCESSING

OCTOBER 1973

4-1

(IMPORTANT INFORMATION ON BACK COVER)

CORRESPONDENCE COURSE
of the
US ARMY ORDNANCE
CENTER AND SCHOOL

ORDNANCE SUBCOURSE NUMBER 905, AUTOMATIC DATA PROCESSING

(8 Credit Hours)

INTRODUCTION

The most significant event that has ever influenced military management is the advent and development of the electronic digital computer. The computer has revolutionized methods of management and it has multiplied the demand placed upon those who manage. By its tremendous speed and pinpoint accuracy, the computer provides military commanders and administrators with complete and continuously up-to-date reports. Such reports, in turn, have given new meaning to the term "management control."

The computer cannot produce answers by itself. Previously designed systems of collecting, sorting, and arranging data must have been established. This subcourse is designed to provide you with a general knowledge of punched card machines and automatic digital computers.

This subcourse consists of two lessons and an examination organized as follows:

Lesson 1 Introduction to Punched Card Machines

Scope - Characteristics of punched card machines, the seven machines that are necessary for punched card data processing, and the basic considerations of report designing.

Lesson 2 Introduction to Automatic Digital Computers

Scope - Generations of digital computers, the six major elements that make up a digital computer system, and the basic differences between business/logistics computers and scientific computers.

Examination

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CHECKLIST OF TEXTS AND MATERIALS FURNISHED

Ordnance Subcourse 905

October 1973

The pamphlets listed below are the only references needed for use with this subcourse. They do not have to be returned to the US Army Ordnance Center and School. Before you start working on this subcourse, check and make certain that you have the lesson answer sheet and the following references:

Suppl Pam 905-1, Introduction to Punched Card Machines	Oct 73
Suppl Pam 905-2, Introduction to Automatic Digital Computers	Oct 73

If any item listed above is missing, notify us at once. This subcourse may contain errata sheets. Make certain that you post all necessary changes before beginning.

Note. - Any references cited in this subcourse, other than those listed above, are general references and are not furnished.

LESSON EXERCISE QUESTIONS

Instructions for use of the answer sheet:

1. The procedure by which you will answer the exercise questions in this subcourse is probably new to you. The information is presented in a programed instruction format where you immediately know whether or not you have answered the questions correctly. If you have selected an incorrect answer, you will be directed to a portion of the study text that will provide you with additional information.

2. Arrange this subcourse booklet and your answer sheet so that they are convenient. Each exercise question has three choices lettered a, b, and c. Your answer sheet has three groups of numbers for questions 1 through 200. The numbers indicated for each question represent the a, b, or c choices. The exercise response list is enclosed with this subcourse. It contains a listing of 3-digit numbers in numerical sequence. Each number is followed by a response that either reinforces a correct answer or gives you additional information for an incorrect answer.

3. To use this system proceed as follows:

a. Read the first exercise question and select the choice you think answers the question correctly. Go to the question 1 area of your answer sheet and circle the 3-digit number that corresponds with the choice you selected.

b. After you have identified the 3-digit number, locate it in the exercise response list. If you selected the right choice, the first word of the response will be "CORRECT." This tells you that you have answered the question correctly. Read the rest of the response which tells why your choice was correct and then go to the next question.

c. If the word "CORRECT" is NOT the first word of the response, you have selected the wrong answer. Read the rest of the response and then turn to the area in your study text that is mentioned. There you will find the information necessary for you to make another choice. Be sure to read all of the response because it will help you select the correct answer and it also provides more information. Line out the incorrect 3-digit response on your answer sheet.

d. After you have reread the reference, select another answer and circle the 3-digit response for that choice. Again check the number of this second choice with the response list to see if your choice is now correct and to obtain more information about your choice. If your second choice is still not correct, line out the 3-digit response on the answer sheet and continue until the correct answer is selected. When you have answered all of the questions in an exercise, count the number of lined out responses and see how well you did.

4. You will notice that the lesson exercise question numbers continue consecutively from lesson to lesson. This allows you to use one answer sheet for the entire subcourse.

5. After you have finished the exercise questions for all lessons, fold and seal the answer sheet so that the USAOC&S address is on the outside. Drop the answer sheet in the mail so the school will know you have completed the study portion of the subcourse and are now ready for the examination.

CORRESPONDENCE COURSE
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LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 905	Automatic Data Processing
Lesson 1	Introduction to Punched Card Machines
Credit Hours	Four
Lesson Objective	After studying this lesson the student will be able to describe the characteristics of punched cards, the seven machines necessary for punched card data processing, and the basic considerations of report designing.
Text	Suppl Pam 905-1
Materials Required	None
Suggestions	None

STUDY GUIDE

Study Supplemental Pamphlet 905-1, Introduction to Punched Card Machines.

EXERCISE

1. Columns on a punched card are combined to form

   a. areas.
   b. zones.
   c. fields.

2. Which is a characteristic of punched cards?

   a. Made from inexpensive paper stock
   b. Require no special storage facilities
   c. Must be nonconductors of electricity

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3. Which factor is an advantage in using punched cards for processing data?

   a. Automatic printing of data on cards as they are punched
   b. Cards can store 80/90 characters per card
   c. Provide a fast means when used as computer input

4. Which standard punched card used by the Army is read by a metallic brush?

   a. 66-column
   b. 80-column
   c. 90-column

5. Which word is recorded in a card containing the following punches in the order shown?

   11 zone and 1 numeric
   11 zone and 6 numeric
   12 zone and 8 numeric
   11 zone and 5 numeric

   a. Army
   b. Jack
   c. John

6. By what set of punches may the letter M be recorded in an 80-column punched card?

   a. A 12-zone punch and a 9 punch
   b. An 11-zone punch and a 4 punch
   c. A 0-zone punch and a 3 punch

7. How many rows can be used on an 80-column punched card for recording alphanumeric data?

   a. 13
   b. 12
   c. 10

8. Which side of an 80-column punched card is referred to as the 12 edge?

   a. Top
   b. Bottom
   c. Left

9. On an 80-column punched card, what are the three top horizontal rows called?

   a. Numeric punches
   b. Zone punches
   c. Letter punches

10. Which control punch is the most common type used in a punched card system?

    a. O
    b. X
    c. Y

11. The 12 punch is also called the

    a. high punch.
    b. control punch.
    c. X punch.

12. What are the seven basic machines of punched card data processing?

    a. Card punch, interpreter, sorter, calculator, accounting machine, reproducing punch, and printer
    b. Card punch, interpreter, sorter, reproducing punch, accounting machine, assembler, and printer
    c. Card punch, interpreter, sorter, collator, reproducing punch, calculator, and accounting machine

13. Which punched card machine is normally used to convert source data into punched cards?

    a. Reproducing punch
    b. Card punch
    c. Document originating machine

14. What is the purpose of verifying?

    a. To check the accuracy of the original keypunching
    b. To print the contents of the card on the top of the card
    c. To report errors by means of a hard copy

15. What name is given to the process of converting punched card holes into human language?

    a. Adapting
    b. Manipulating
    c. Interpreting

16. What is the maximum number of characters that an interpreter can print on one line of a punched card?

    a. 38
    b. 60
    c. 80

17. Which item of punched card equipment performs the second step in machine accounting?

    a. Collator
    b. Sorter
    c. Verifier

18. Which punched card machine can accomplish the functions of sequence checking, merging, and matching?

    a. Collator
    b. Sorter
    c. Verifier

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19. The automatic copying of punched card information from a master card into one or more detail cards that follow it is called

    a. duplicate keypunching.
    b. data repetition.
    c. gang punching.

20. Which item of punched card equipment uses an internal magnetic core storage for performing its designed function?

    a. Interpreter
    b. Calculator
    c. Accounting machine

21. Which data processing machine performs the function of summarizing in punched card operations?

    a. Accounting
    b. Collator
    c. Calculator

22. The functions of sorting, sequence checking, selecting, editing, counting, accumulating, and printing are combined in the

    a. accounting machine.
    b. keypunch read/write unit.
    c. electronic statistical machine.

23. Which type of punched cards are automatically machine created as a result of processing tape records?

    a. Dual cards
    b. Output cards
    c. Transcript cards

24. In determining the field size of a punched card format, how many columns are generally sufficient for recording 95 percent of individual names?

    a. 22
    b. 18
    c. 14

25. Which factor should be considered when designing a dual card?

    a. Provide one area of the card for handwritten data
    b. Make field headings explicit and abbreviated
    c. Use corner cuts to distinguish card types

CORRESPONDENCE COURSE
of the
US ARMY ORDNANCE CENTER AND SCHOOL

LESSON ASSIGNMENT SHEET

Ordnance Subcourse No 905	Automatic Data Processing
Lesson 2	Introduction to Automatic Digital Computers
Credit Hours	Three
Lesson Objective	After studying this lesson the student will be able to describe the generations of digital computers, the six major elements that make up a digital computer system, and the basic differences between business/logistic and scientific computers.
Text	Suppl Pam 905-2
Materials Required	None
Suggestions	None

STUDY GUIDE

Study Supplemental Pamphlet 905-2, Introduction to Automatic Digital Computers.

EXERCISE

26. What is the significant word in the phrase "automatic data processing" that signifies the big difference between present systems and former methods of calculations?

    a. Automatic
    b. Data
    c. Processing

27. What are the total requirements for a total ADPS?

    a. Hardware, personnel, and computer
    b. Hardware, software, and personnel
    c. Programs, personnel, and procedures

28. What is the major advantage of automatic data processing over other methods of processing data?

    a. Speed
    b. Accuracy
    c. Ability to make decisions

29. The word "digital" would be used to describe a computer when answering which question?

    a. What is its size?
    b. How does it represent data?
    c. What is its purpose?

30. Which type of computer could be BEST used for control purposes in the petroleum industry?

    a. Analog
    b. Digital
    c. Hybrid

31. Which characteristics are found in business applications of a computer?

    a. Large amount of input, large amount of computation, and small amount of output
    b. Large amount of input, small amount of computation, and large amount of output
    c. Small amount of input, small amount of computation, and large amount of output

32. Why do computers use the binary system instead of the decimal system?

    a. Much more data may be represented by the binary system
    b. Computers are made up of switching devices that have only two definite states
    c. The cost of a computer using a decimal system would be prohibitive

33. Which of the binary numbers listed below represents the decimal representation 224?

    a. 11100111
    b. 10111101
    c. 11100000

34. Which decimal number represents the binary number 10011001?

    a. 185
    b. 153
    c. 137

35. Which decimal number is the result of multiplying the binary number 0111 by 0101?

    a. 25
    b. 30
    c. 35

36. Which response correctly converts the straight binary number 1000110001 to binary-coded decimal?

a. 1010 1100 0100
b. 0101 0110 0001
c. 0011 0101 1010

37. What are the basic functional components of an ADPS?

a. Input, processing, and output
b. Control, storage, and arithmetic
c. Input, storage, and output

38. Which type of device brings data to the computer and carries the processed data away from it?

a. Control unit
b. Output element
c. Communication element

39. Probably the earliest known calculating device is

a. the abacus.
b. Pascal's calculator.
c. Napier's bones.

40. The first machine to accept information recorded on a punched card was

a. Pascal's calculator.
b. Jacquard's loom.
c. Babbage's analytical machine.

41. The first generation of computers was characterized by the use of

a. vacuum tubes.
b. transistors.
c. solid state circuitry.

42. Which element is characteristic of present day computers?

a. Transistors
b. Solid state circuitry
c. Microcircuitry

43. The purchase price of a computer can be estimated by multiplying the monthly rental fee times

a. 36.
b. 42.
c. 48.

12

44. Which type of computer is usually used to process data for the military services?

a. General purpose, digital, and business-type
b. Special purpose, digital, and business-type
c. General purpose, analog, and scientific

45. Which storage device should be selected for use in the central processing unit if fast access time is the total determining factor?

a. Magnetic drum
b. Magnetic disk
c. Thin film

46. In storing data CRAM uses a magnetic

a. disk.
b. card.
c. tape.

47. Which device is used for nonaddressable bulk storage in computer operations?

a. Magnetic card
b. Magnetic core
c. Magnetic tape

48. What is the most efficient input or output medium for a computer?

a. Magnetic tape
b. Punched cards
c. Paper tape

49. What is the most frequently used type of input which may be created as a byproduct of other operations such as addressing machines, bookkeeping machines, and typewriters?

a. Punched cards
b. Magnetic tape
c. Punched paper tape

50. Which output device offers the greatest potential to the Army?

a. Audio response units
b. Visual display
c. Computer console

13

EXERCISE RESPONSE LIST

SUBCOURSE 905
AUTOMATIC DATA PROCESSING

OCTOBER 1973

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND
MARYLAND

NOTICE

The inclosed responses are listed in numerical order. After making a circle around the number of your choice on the ANSWER SHEET, check the same number on the exercise response list. If you selected the correct answer, the response will indicate it with the word "CORRECT" appearing as the first word. Read the response for further information and then proceed to the next question. If the response shows you have not selected the correct choice, read the information presented to find out why your choice was wrong and where you can find the correct answer. The suggested references are designed to cover major teaching points in each lesson, thus reinforcing the student's learning process.

REMINDER!! Be sure to PRINT your name, grade, social security account number, subcourse number, and date in the top left corner of your answer sheet before you start your first exercise.

RESPONSE NUMBER	RESPONSE
101	CORRECT. The collator performs many functions. It is often referred to as an automatic file clerk. A few of its basic functions are sequence checking, merging, and matching (para 14b).
103	CORRECT. The card verifier is similar to the card punch but its main function is to check the data in a card rather than to punch data into a card (para 10b(1)).
104	No. Refer to para 3c.
110	CORRECT. An 11-zone punch and corresponding numeric punches 1 through 9 are used for letters J thru R (fig 3).
112	Wrong. Refer to para 10b.
113	No. Refer to para 23a.
116	No. See para 33i(2)).
117	CORRECT. When digital and analog data representations are combined a hybrid computer is produced. Hybrid representation is used for control purposes in the petroleum industry (para 4a(3)).
119	No. Refer to para 11.
124	No. See para 14.
129	CORRECT. 0111 = 7 0101 = x5 0111 35 0000 0111 0000 100011 (35 in decimal) (para 12)
133	CORRECT. These cards are automatically machine created as a result of processing disk storage records, tape records, or other cards (para 19a).
143	CORRECT. The top section of an 80-column punched card is restricted to zone punches. These are the 12 punch or high punch, 11 punch or X punch, and zero punch (para 7b).
152	CORRECT. We have had many machines in the past that have been described as data processing systems, but it is the addition of the word "automatic" that makes the difference. Automatic means that the work is done with a minimum of human intervention and the manipulation of the information takes place within a complete, closed unit (para 2c).

16

156 Wrong. Refer to para 13.

166 Incorrect. See fig 3.

178 CORRECT. This is done primarily by sensed alphabetic or numeric data that is punched in a card and printing it on the same card (para 11).

179 CORRECT. All data processing involves at least three basic considerations: source data or input entering the system; planned processing within the system; and the end result or output from the system (para 15a).

188 CORRECT. Communication devices, especially those within the category of data transmission devices, are used for moving data to the data processing center and away from it (para 16b).

191 No. See para 24b.

192 Wrong. See para 4a(3).

197 Wrong. Refer to para 7 and 10a.

204 Wrong. Refer to para 33i(2).

213 CORRECT. In classifying computers we must inquire into the way in which a computer internally stores or represents data. Data can be represented in one of two ways: analog or digital (para 4).

215 CORRECT. Although the origin of the abacus remains obscure, it has been used for addition and subtraction since ancient times (para 17a).

223 No. See para 3d(1).

231 No. See para 8b.

235 CORRECT. These machines are capable of doing the work of more than 100 people and are the workhorses of an ADPS facility (para 9a).

236 No. See para 12.

241 Wrong. See para 6a(4).

242 CORRECT. This machine can perform all of the functions noted. It is designed for high speed classifying and counting and for preparing printed statistical reports (para 17b).

243 Incorrect. Refer to para 4 and 5.

248 CORRECT. When designing a dual card use one area of the card exclusively for handwritten data so that it will not be obliterated by punching (para 19e(4)).

253 Wrong. Refer to para 26c.

256 Wrong. Refer to para 4.

259 Wrong. See para 9.

264 No. Refer to para 4a(3).

274 CORRECT. Third generation (present day computers) use microcircuitry to replace the second generation transistors (para 18d(3)).

276 CORRECT. Although the card has 80 columns for punching purposes, the width of the printed characters used in interpreting allows only 60 characters to be printed across the card (para 11a).

277 No. See para 19.

278 Incorrect. See para 13.

279 No. See para 7a.

288 No. Refer to para 19e.

289 CORRECT. This punch is sometimes used for control purposes; when it is so used, it is referred to as the high punch. If it is used for control purposes, it is usually referred to as an R punch (para 8b).

290 No. See para 7b and fig 3.

292 CORRECT. Total 224 (para 8).

0 in the 1's position = 0

0 in the 2's position = 0

0 in the 4's position = 0

0 in the 8's position = 0

0 in the 16's position = 0

1 in the 32's position = 32

1 in the 64's position = 64

1 in the 128's position = 128

293 Incorrect. See para 19c.

295 Incorrect. See para 2c.

296 No. Refer to para 2d.

298 No. Refer to para 9.

299 Incorrect. See para 24a(2).

309 Wrong. Refer to para 4 and 5.

324 Wrong. Refer to para 7a.

326 Wrong. Refer to para 19a.

18

330 Wrong. See para 19e.

333 Wrong. Refer to para 18d.

336 Incorrect. Refer to para 11.

341 Wrong. Refer to para 4b(2)

342 Wrong. See para 8a.

347 Wrong. Refer to para 12c.

349 Incorrect. See para 18d(3).

356 Wrong. See para 17d.

358 CORRECT. Magnetic tape is usually produced by the computer in the form of output and is the most efficient input or output medium for a computer (para 26c).

362 Wrong. See para 14.

369 CORRECT. Gang punching is automatically copying punched information from a master card. This function is performed by the reproducing punch (para 14b).

375 No. Refer to fig 3.

378 CORRECT. The calculator performs arithmetic operations at a speed of 200 cards a minute. To perform these operations, the calculator uses an internal magnetic core storage (para 15b).

379 Wrong. Refer to para 30.

382 CORRECT. One of the greatest advantages derived from the use of punched card records is the ability to sort and select with a machine known as a sorter. This machine performs the second step in machine accounting (para 12).

390 No. See para 3a.

391 Wrong. See para 14b.

392 CORRECT. Thin film storage is the most recently developed type of storage to be placed or used as the internal storage unit for computers. This storage device has the fastest access time (para 23a).

394 CORRECT. The estimated life of a computer is 42 months; therefore, this figure is used to estimate the purchase price (42 x monthly rental) (para 19b).

396 CORRECT. The very first operation in a punched card system is the job of transcribing the written records into punched cards by use of the card punch (9b).

397 CORRECT. The CRAM device uses magnetic cards having seven recording tracks and 3,100 alphanumeric characters can be stored on each track. This gives the card a storage capacity of 21,700 alphanumeric characters (para 24a(2)).

408 Incorrect. See para 23a.

409 No. See para 9a.

412 CORRECT. There are three nonaddressable bulk storage media: magnetic tape, punched cards, and punched paper tape (para 24b).

416 CORRECT. Through the adaption of office machines to punch or read paper tape as a byproduct of their regular operations, communication with a data processing machine is now possible (para 30).

420 Wrong. Refer to para 7b, and fig 3.

421 CORRECT. This capability provides a visual check for correctness and easy identification (para 4 and 5).

423 Wrong. Refer to para 2c.

426 Incorrect. Refer to para 15b.

427 Wrong. Refer to fig 3.

429 Wrong. See para 9b.

432 Wrong. Refer to para 3a.

437 CORRECT. Business type computers in the mid-1950's marked the beginning of our computer generations. They required the use of many thousands of vacuum tubes (para 18d).

452 Incorrect. Refer to para 11a.

457 No. See para 17d.

463 Incorrect. See para 7 and 10a.

465 No. See para 16b.

471 CORRECT. The computer is used for either scientific or business purposes. Business applications are characterized by a large amount of input, a small amount of computation, and a large amount of output (para 4b(2)).

482 Wrong. See para 17a.

483 CORRECT. This punched card is read by a metallic brush completing an electrical circuit through holes in the card (para 6a(4)).

20

485 CORRECT. For punching names 20 columns are generally sufficient; however, a study regarding this area indicates that 95 percent of names of individuals can be recorded in 18 columns or less (para 19c(4)).

486 CORRECT. Printed reports are prepared automatically by accounting machines which read the holes in the cards and print the reports. This step in machine processing is called summarizing (para 16).

490 No. See para 14.

491 Incorrect. See para 15a.

492 Wrong. See para 17b.

493 CORRECT. These devices have been developed largely in connection with military command and control systems in conjunction with tactical operations (para 33i(2)).

496 Incorrect. See para 19.

500 No. See para 30.

501 Incorrect. See para 3c.

510 Wrong. Refer to para 11a.

521 No. Refer to para 14b.

522 No. See para 24a(2).

523 No. See para 18d.

524 Incorrect. See para 12.

527 No. See para 6a(4).

529 No. See para 10b.

536 CORRECT. Since punched cards are read by electrical or mechanical means, we must designate a certain number of columns for data separated by a space which form fields (para 3c).

537 No. See para 4.

539 CORRECT. Computers that will be used in processing military data will usually be the general purpose, digital, and business-type computers. Size will vary according to the job involved (para 19c).

541 No. Refer to para 17b.

547 Incorrect. Refer to para 8a.

562 CORRECT. The 80-column card system has both zone and numeric punches. The third zone punch serves as both a zone and numeric punch giving the card 13 rows for storing alphanumeric data (para 7b).

563 Wrong. Refer to para 15a.

572 No. See para 12c.

573 CORRECT. Without a doubt the major advantage of a computer over punched cards and other systems is speed. For example, 10,000 simple mathematical problems can be solved in one-tenth of a second (para 3a).

577 Wrong. See para 8.

578 Wrong. Refer to para 8b.

579 Wrong. Refer to para 7b and fig 8.

581 No. See para 4b(2).

582 Wrong. Refer to para 14.

584 Incorrect. Refer to para 16b.

591 CORRECT. A total ADPS is an interacting assembly of personnel, procedures, and equipment. These elements are described as hardware, software, and personnel (para 2d).

594 CORRECT. 1000110001 converts to the decimal number 561 which is indicated in BCD as 0101 0110 0001 (para 13).

595 CORRECT. In addition to cards being of the finest stock available, they must be nonconductors of electricity to allow for correct reading by ADP equipment (para 3d(1)).

597 No. See para 19a.

612 CORRECT. By use of fig 3 you determined that the punches indicated the word John.

617 CORRECT. The requirement for a binary numbering system is imposed by the nature of the electronic equipment now available (para 7a).

627 CORRECT. This device, invented in 1745 and perfected in 1801, was the first machine to accept information recorded on punched cards (para 17d).

628 Wrong. See para 15b.

630 CORRECT. The top edge of the card contains the 12 punch and is referred to as the 12 edge (para 7 and 10a).

634 No. Refer to para 17a.

635 Incorrect. Refer to para 9a.

636 No. Refer to para 9b.

637 No. See para 19c.

639 Wrong. Refer to para 18d(3).

22

642 Wrong. Refer to para 24b.

643 Incorrect. Refer to para 2d.

647 Wrong. Refer to para 19.

657 Wrong. See para 3d(1).

661 No. See para 7b and fig 8.

662 No. See para 26c.

679 CORRECT. 2/153 (para 9)

```
                2/153
                2/76-1
10011001        2/38-0
                2/19-0
                2/ 9-1
                2/ 4-1
                2/ 2-0
                2/ 1-0
                  0 1
```

685 CORRECT. The 11 punch, which is the middle zone punch, is the most common control punch. When used for control purposes it is called an X punch (para 8a).

690 No. See fig 3.

691 Incorrect. Refer to para 8.

699 No. Refer to para 19.

ANSWER SHEET

FOR KEYPUNCH ONLY

001 444
S/C ORD 905 3

NAME _____
LAST FIRST MI

GRADE _____ SSAN _____

ADDRESS _____

_____ ZIP Code

If this is a new address check here ☐

NOTICE

Refer to the instructions preceding lesson exercise question 1 in your study text for information on the use of this answer sheet and the exercise response list. After your selections of choices for all exercise questions have been circled, tear this sheet out of the subcourse, fold it as instructed on the address side, and mail it to the school.

	a	b	c
1.	104	501	536
2.	223	657	585
3.	421	309	243
4.	241	483	527
5.	375	166	612
6.	660	110	427
7.	562	290	420
8.	630	197	463
9.	579	143	661
10.	547	685	342
11.	289	578	231
12.	635	409	236
13.	429	396	636
14.	103	112	529
15.	119	336	178
16.	510	276	452
17.	236	382	524
18.	101	490	362
19.	521	391	369
20.	628	378	426
21.	486	124	582
22.	541	492	242
23.	326	133	587
24.	293	485	637
25.	248	330	288
26.	152	295	423
27.	296	591	643
28.	573	390	432
29.	537	213	256
30.	192	264	117
31.	581	471	341
32.	279	617	324
33.	691	577	292
34.	250	679	298
35.	347	572	129
36.	156	594	278
37.	179	563	481
38.	465	584	188
39.	215	634	482
40.	457	627	356
41.	437	523	333
42.	349	639	274
43.	277	394	647
44.	539	496	699
45.	113	408	392
46.	522	397	299
47.	191	642	412
48.	368	662	253
49.	500	379	416
50.	116	493	204
51.	164	415	533
52.	629	195	520
53.	311	505	498
54.	167	239	323
55.	304	442	227
56.	631	360	590
57.	677	206	425
58.	389	402	147
59.	316	638	403
60.	194	553	268
61.	363	570	477
62.	284	367	109
63.	207	545	648
64.	422	138	506
65.	615	504	417
66.	145	407	218
67.	590	205	376
68.	621	177	603
69.	468	669	320
70.	134	497	694
71.	385	448	170
72.	200	555	307
73.	674	184	516
74.	567	290	662
75.	228	608	161
76.	372	141	696
77.	549	665	210
78.	444	220	313
79.	688	559	173
80.	100	344	531
81.	245	405	460
82.	360	440	624
83.	600	365	122
84.	233	526	339
85.	565	282	271
86.	176	684	488
87.	434	150	575
88.	661	363	154
89.	225	474	672
90.	400	136	352
91.	371	536	202
92.	513	296	446
93.	106	654	543
94.	644	262	454
95.	387	518	181
96.	159	374	605
97.	557	127	332
98.	410	619	212
99.	247	451	587
100.	328	551	186
101.	199	301	614
102.	683	131	459
103.	431	607	250
104.	281	480	512
105.	561	286	318
106.	115	507	238
107.	601	222	419
108.	414	190	659
109.	355	611	172
110.	687	439	329
111.	140	381	569
112.	384	667	193
113.	610	118	556
114.	148	447	209
115.	462	336	623
116.	338	666	404
117.	108	224	300
118.	589	684	142
119.	306	121	640
120.	183	470	273
121.	625	346	515
122.	484	255	399
123.	217	698	436
124.	334	503	139
125.	593	388	291
126.	111	650	331
127.	633	252	479
128.	216	438	528
129.	411	196	671
130.	558	169	396
131.	368	697	275
132.	144	467	666
133.	476	502	123
134.	602	258	450
135.	229	303	598
136.	188	441	305
137.	472	680	125
138.	369	157	576
139.	534	380	244
140.	675	221	401
141.	287	589	608
142.	354	695	189
143.	641	297	499
144.	163	596	386
145.	546	322	257
146.	226	449	514
147.	418	130	609
148.	506	395	196
149.	294	604	406
150.	424	158	353
151.	645	219	548
152.	128	583	254
153.	321	453	676
154.	171	364	620
155.	653	237	464
156.	435	692	146
157.	560	102	337
158.	310	532	270
159.	214	475	571
160.	678	182	348
161.	428	613	114
162.	201	552	443
163.	509	373	660
164.	180	481	230
165.	357	272	554
166.	586	366	174
167.	343	151	686
168.	120	519	495
169.	626	246	314
170.	487	652	203
171.	286	433	540
172.	618	156	361
173.	473	658	249
174.	211	566	489
175.	182	351	681
176.	306	466	588
177.	538	265	105
178.	445	187	648
179.	153	542	312
180.	234	655	458
181.	670	283	550
182.	302	430	148
183.	574	317	240
184.	165	345	564
185.	325	663	261
186.	622	176	456
187.	592	269	616
188.	208	517	327
189.	585	413	107
190.	377	673	132
191.	135	319	481
192.	683	185	370
193.	494	251	525
194.	544	469	232
195.	267	530	649
196.	668	263	455
197.	315	160	632
198.	137	511	340
199.	568	383	280
200.	478	689	126

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SUPPLEMENTAL PAMPHLET

905-1

INTRODUCTION TO PUNCHED CARD MACHINES

OCTOBER 1973

4-1

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND
MARYLAND

SUPPLEMENTAL PAMPHLET 905-1

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SECTION I. INTRODUCTION

1. GENERAL.

a. The idea of conveying information by a series of holes in a card is not a new one. The first known use was the Jacquard loom in the early 18th century. In this case, the machine moved punched sheets of stiff paper past a reading mechanism which activated a thread selector. The paper patterns (or programs) could be easily changed, and the various colored threads would weave different designs into the tapestries and rugs.

b. In the latter part of the 19th century, we again see punched cards used, this time in the United States. The Census Bureau at that time had problems. In 1880 the census was taken as required by the Constitution, but it took 7 years, until 1887, to determine that there were 50 million people in the United States and to tabulate the vital statistics. The problem was a difficult one: it was estimated that, using the same methods, it would take 12 years to tabulate the data from the census of 1890 - until 1902, 2 years after another census! However, Dr. Hermann Hollerith, a statistician working for the Census Bureau during that time, had a solution to the problem - automation. His system utilized a 3-inch by 5-inch card divided into quarter-inch squares. Information was carried in the card by means of holes punched out with a regular ticket punch. The card was read by a pin press consisting of a hard rubber plate with a cup under each square position. Each cup was filled with mercury and connected to an electromagnetic counter that could count from 1 to 10,000. A hinged box above the plate contained a spring-activated pin corresponding to each cup. In operation, a card was placed normally in the pin press and the box lowered to activate the appropriate counters. Speeds of 50 to 80 cards a minute were possible using this device. The Census Bureau adopted Dr. Hollerith's system and despite the increase in the population from 50 to 62 million, the accounting went smoothly. Dr. Hollerith had started something, and it is still going, stronger than ever, today.

2. BACKGROUND.

a. Many of the checks, bills, and other pieces of correspondence that you receive today have different physical characteristics from those you received in years past. They are smaller, thicker than paper, and made of cardstock. These cards are decorated with small, rectangular holes punched in a disorderly fashion. However, you would not question the authenticity of these perforated documents since nearly every American citizen has by now seen and used the ever-present punched card.

b. Since the Army, as well as industry and other large organizations that are involved in large-scale data processing, is gradually changing to computers, you may question the propriety of devoting time to punched card methods. Actually, there are many reasons why administrative personnel of the Army should be familiar with punched-card accounting methods. Three of the most important reasons follow:

(1) Conversion to computer equipment has evolved successfully where a punched card system previously existed.

(2) Computers are far more expensive than punched card machines. Considering the cost, punched card methods may be a better solution to a data processing problem than conversion to a computer.

(3) Punched card methods are widely used in the Army for personnel, financial, and stock accounting. Despite the increased use of computers, the use of punched cards is also increasing daily.

SECTION II. THE PUNCHED CARD

3. COMMON CHARACTERISTICS. A punched card is made of sturdy, high quality paper that is capable of withstanding the changes in temperature and humidity that would alter the shape of ordinary paper and cause it to jam the machines. Although there are different types of punched cards, all of them have definite common characteristics. Before considering the specific peculiarities of each of the more popular cards, let us examine the similarities of all punched cards. (Appendix II is a glossary of punched card terms that further clarifies many of the following items.)

a. Recording. Data is recorded in all punched cards by punching out or removing a portion of the card. The punched holes are symbols of a new language that might well be considered machine language since it enables the equipment to process data mechanically.

b. Columns. All punched cards are divided into columns. One column of a card is required to record one character or digit of information. To record the name "Smith," five columns are required—one for each letter. If we want to leave a space and record the first name, the space requires a column to be left blank. Therefore, the amount of data that we can record in a punched card is limited by the number of columns that the card contains.

c. Fields. Columns on a punched card are combined to form fields. Consider the columns needed to punch a name. Since punched cards are read by electrical or mechanical means, we must designate a place or a certain number of columns needed to record an individual's name. If we wish to record the first 15 characters of each person's name, we must set aside 15 consecutive columns of the card and designate them the "name field" (fig 1). Separate fields usually are established for a social security number (SSN), grade, and other required information. Thus, a field is one column or a group of consecutive columns of a punched card set aside for a specific item of information.

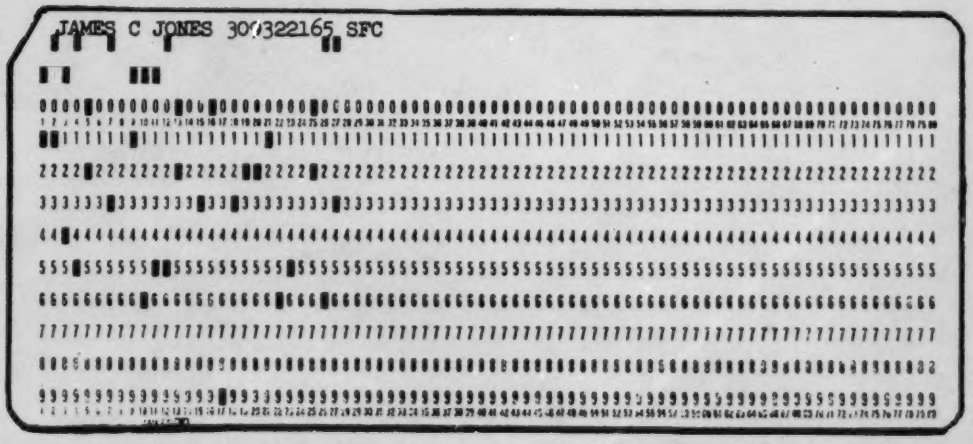

Figure 1. Punched card showing name, SSN, and grade fields.

d. Physical characteristics. Since punched cards are punched, sorted, merged, read, and calculated by machines, they all must have certain common physical characteristics.

(1) Stock. The rate of speed with which these cards must pass through machines demands that the cards be of the finest stock available. In addition, cards must be nonconductors of electricity.

(2) Storage. This is a basic problem at all installations using punched cards. Cards must be stored in a warm, dry place; if not, they absorb moisture from the air and cannot be processed through machines. They must also be kept under pressure; otherwise, they curl or bend and cannot be properly processed by the machine.

(3) Handling. Printed on nearly all punched cards is the inscription "Do not fold, spindle, or mutilate." Those cards must again be machine processed, which is almost impossible if the cards have been mistreated.

(4) Reading. Cards are read by use of pins or brushes in electrical accounting machines. Cards may also be read by photoelectric cells.

(5) Color. Punched cards are manufactured in various colors. The cards may be a solid color; for example, yellow, green, red, blue, or white. They may be colored on the 12 edge of the cards or they may have a stripe through the center. The different colors are used as a means of identification. Colors help the operators to distinguish one record file from another.

(6) Corner cut. A diagonal cut at either the left or right corner of a card is one means of easy identification.

4. ADVANTAGES. The use of punched cards for processing data offers many advantages. Foremost among these are:

a. Punched cards are compatible with PCM's which can be used to print, sort, and merge them.

b. They are available when changing over from a PCM to a computer operation.

c. They are easy to prepare and errors are easy to correct and detect.

d. Input data can be prepared simultaneously on several card punch machines, and the cards can be collated before computer input.

e. They can be sorted, corrected, or manipulated manually.

f. Formats can be designed for a particular application.

g. They can be used to operate a high speed printer or to convert data to paper or magnetic tape.

h. Information can be read directly from cards and transmitted by transceiver over normal telephone lines to remote stations.

i. Cards can be used as both source documents and records and as direct input to the computer.

j. Data can be printed automatically on cards as they are punched, or interpreted after punching, to provide a visual check for correctness and easy identification.

5. DISADVANTAGES. The use of punched cards also offers several disadvantages. Foremost among these are:

a. Though they are inexpensive, cards wear out through constant handling and are easily torn or mutilated.

b. They are susceptible to damage by humidity, are difficult to read by machine when damp, and may swell or warp to such an extent that they cannot be processed mechanically.

c. Cards stack at about 140 per inch, requiring considerable storage space for large operations. Extra space is needed to store supplies of blank cards.

d. Cards are limited to 80/90 characters for storing data.

e. Data placed on cards cannot be erased and replaced with new data.

f. Cards are slow when used as computer input or output.

6. CLASSIFICATIONS. The two standard classifications of punched cards are the 80-column punched card and 90-column punched card. Some of the other classifications include the 51- and 66-column punched cards. Punched cards may be designed in almost any size or shape to meet the needs of the users; for example, a mark-sensing card or a port-a-punch card. Let us examine the two standard classifications of punched cards.

a. The 80-column punched card. Perhaps the punched card that you are most familiar with in the Army is the 80-column card (fig 1). It is used for personnel, financial, and stock accounting.

(1) Columns. This card has 80 columns which allow 80 characters of information to be recorded. These columns begin with column 1 at the left side and go through column 80 at the right. You will learn more about this 80-column card later.

(2) Size. This card is 3-1/4 inches by 7-3/8 inches.

(3) Punching. Rectangular punches that follow a systematic punching system are used to encode information in this card. This enables us to read the card manually. (Appendix III explains how to interpret an 80-column punched card.)

(4) Reading. This card is read by a metallic brush completing an electrical circuit through the holes in the card.

b. The 90-column punched card. This card (fig 2) is currently used by a few financial and stock accounting units in the Army.

(1) Columns. This card is divided into two halves horizontally. Basically, this card has 90 columns which permit 90 alphanumeric characters to be recorded. However, this number can be expanded to a strictly numeric card of 108 characters. Usual procedure divides the card into columns 1 through 45 in the upper half and columns 46 throuh 90 in the lower half.

(2) Size. The 90-column card is the same size as the 80-column card; i.e., 3-1/4 inches wide and 7-3/8 inches long.

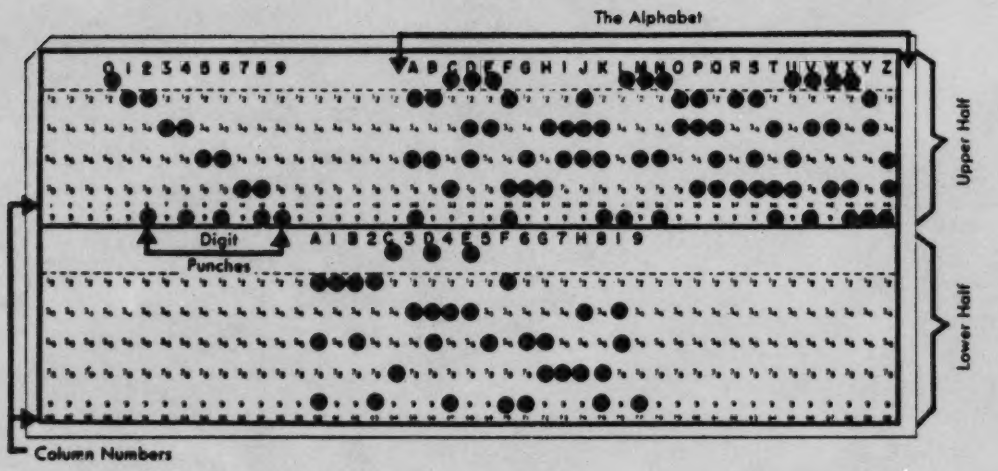
The Alphabet
0 1 2 3 4 5 6 7 8 9
A B C D E F G H I J K L M N O P Q R S T U V W X Y Z
Upper Half
Digit
Punches
A 1 B 2 C 3 D 4 E 5 F 6 G 7 H 8 I 9
Lower Half
Column Numbers

Figure 2. The 90-column punched card.

(3) Punching. The punches are round and the machine code is complex. For odd numbered digits and zero a single hole is punched in the position of the number desired. For even numbered digits a hole is punched in the 9 position and a second hole is punched in the position that is one number lower than the number desired. Thus, holes punched in the 9 and 1 positions represent a 2, and holes in the 9 and 5 positions represent a 6. For alphabetic information, combinations of two or three holes in a single column are used. Ten of the alphabetic characters use two-hole combinations and the remaining 16 alphabetic characters use three-hole combinations. It is very difficult to read a 90-column card manually. The machine code was developed to fit the engineering needs of the equipment, and the human eye cannot detect the specific position of the punched hole.

(4) Reading. The cards are read mechanically by a set of metal pins going through the holes in the card causing the data to be recorded.

c. Other punched card systems. At the present time the Army is using only the two standard types of punched cards just discussed (the 80- and 90-column cards). Other types of punched cards are usually smaller and are frequently used for production and inventory control. Possibly you have seen some of these smaller perforated cards attached to clothing, hardware, and other items in large department stores. There are various versions of the punched-card system used in nearly every aspect of modern day data processing.

7. READING. The holes punched in cards are intended to be read by machines, but some can also be read by the human eye. The machine language of 80-column cards is easy to learn. As we discuss the 80-column card, refer to figure 3 which graphically explains the system used for recording information.

a. Directly below the line of zeros at the top of the card and also at the bottom of the card there are numbers ranging from 1 through 80. Each of these numbers designates a column of the card. Printed in each column in a larger type are numerals ranging from 0 to 9. To record any numeric character (0, 1, 2, 3, 4, 5, 6, 7, 8, or 9), simply punch the position that represents that number. Only one punch for each column can be used to record a numeral. For numbers of two or more digits, two or more columns are used, each column representing its corresponding digit within the larger number.

31

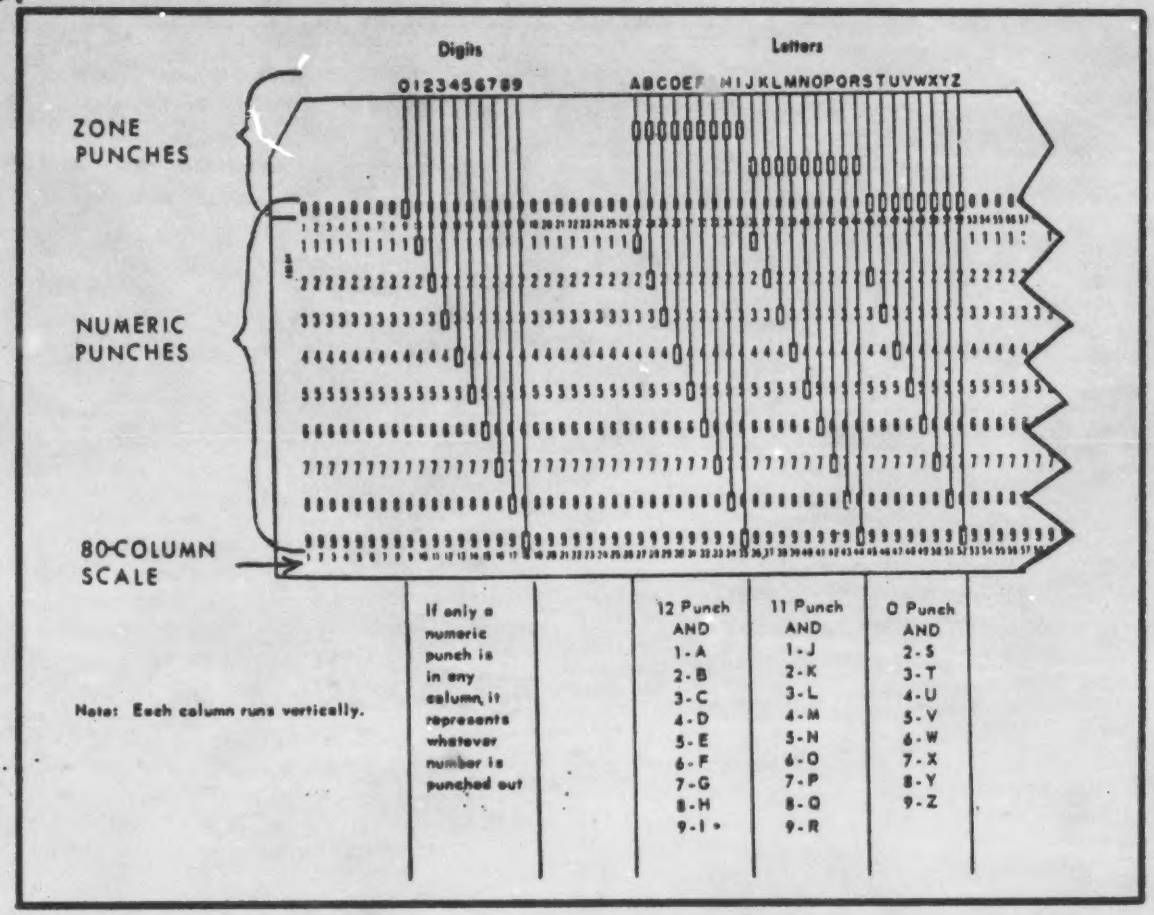

Figure 3. The 80-column card system.

b. Notice on the card (fig 3) the section that shows alphabetic information. As shown at the left edge of the card, the top section is restricted to zone punches. To record letters of the alphabet (alphabetic characters), we need a combination of a numeric punch and a zone punch. The three zone punches are given names. The uppermost punch is the 12 punch or high punch. The one immediately below this is the 11 punch or X punch, since it is used to control machine operations. The third zone punch serves as both a zone punch and the numeric zero punch.

c. The alphabetic characters A through I are composed of two punches, the 12-zone punch and a numeric punch. The alphabetic character A is represented by combining the 12-zone punch with a 1 punch in the same column; 12 and 2 represent the letter B; and so on through 12 and 9 which represent the letter I.

d. Similarly, when punching J through R, the 12 is replaced by the 11 punch or X punch. The character J is represented by combining the 11-zone punch and a 1 punch; the 11 punch and the 2 equal K; and so on through the 11 punch and the 9 which equal R.

41

e. The 0 punch position is used as the zone punch to present the remaining letters of the alphabet. However, when we divide the 26 letters of the alphabet into three groups, we have only eight characters in the last group. Therefore, although we started with a zone punch and a 1 in the other groups, we begin with the 0 and 2 to get the letter S, the first letter of the final group, S through Z. A combination of 0 and 3 equals T, and so on through the combination 0 and 9 which equals Z.

f. Other characters such as "$," "*," "%," and "/" are made by zone punches alone or by combinations of zone and numeric punches in one column (fig 3A).

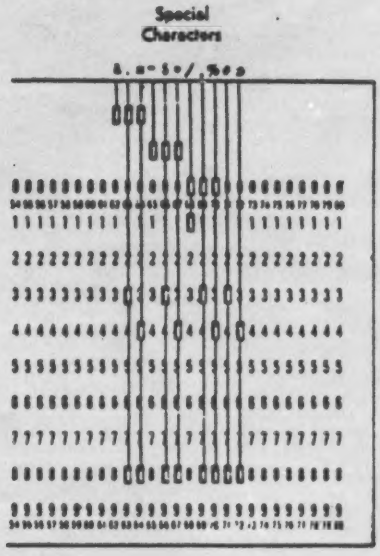

Figure 3A. Special characters.

g. In appendix III is a practical exercise in reading punched cards. If you desire, you may work the practical exercise at this time. The answer to each problem appears at the top of the page following the problem.

8. CONTROL PUNCHES. The functions of certain machines can be controlled by the presence of certain punches in specific card columns. When holes are punched in cards for this purpose, they are called control punches.

a. The most common control punch is an 11 punch. When an 11 punch is punched in a card for control purposes, it is usually called an X punch. In alphabetic punching it is referred to as an 11 punch.

b. Another punch sometimes used for control purposes is the 12 punch. When this punch is used it is referred to as a high punch. Some people in this line of work call the high punch, when used for control purposes, an R punch.

c. The 12 and X punches can also be used for other than machine control. They can be used to identify cards or files and to print special characters. For example, the 12 punch represents the ampersand and the X punch identifies a plus or minus amount punched in a card.

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d. Any of the other punches can be used for control purposes. When used in that capacity they are called digit punches. For example, grade is identified in the cards by digit punching. If an SFC is identified by a 7 punch, we can control the counters of the machine to add only those cards with a 7 punch in one counter or another digit punch in another counter. Thus, we can accumulate a total of each grade in a particular counter.

SECTION III. PUNCHED CARD EQUIPMENT

9. GENERAL.

a. The seven basic machines of punched card data processing (card punch, interpreter, sorter, collator, reproducing punch, calculator, and accounting machine) are capable of doing the work of more than a hundred people. Furthermore, the machines can do the work more accurately. Those seven machines, which are the workhorses of an electric accounting machine facility, can be used to process the data and are necessary in our Government and industry. These manmade devices have the ability to understand and act upon information presented to them in their language—the punched hole.

b. Just as punched holes in the paper rolls can produce music on a player piano, so punched holes in a card can produce reports. These punched cards alleviate the business of recordkeeping. The planning and handling of supplies, records, and personnel services depend upon accurate and up-to-date knowledge of details, which in turn depend upon the compilation of reports and written records of many types. Electric accounting machines (punched card machines) are used to great advantage in preparing these reports. The very first operation in the whole process is the job of transcribing the written records into punched cards. Therefore, the first machine we will discuss is the card punch. This is the machine that accomplishes the recording step in machine accounting and the one that we use to create the issue transaction card from the line item on the requisition form.

10. CARD PUNCH.

A card punch (fig 4) can be used to punch numeric, alphabetic, and special character information. (Under certain circumstances this machine can also print at the top of each column the character represented by the punched holes in that column.) The keyboard is connected to the punch by a cable and can be moved anywhere on the reading board that is convenient for the operator. On the keyboard a group of right-hand keys serve for punching digits as well as letters, with the shift from one to the other made automatically. This permits the operator to punch numeric and alphabetic fields with both hands and, without shifting from the "home" position, to punch a numeric character or field with the right hand only. This frees the left hand for handling documents. A light depression of a key on the keyboard causes a punching die to be driven automatically through the card, thereby cutting one or more holes in the column to correspond with the key depressed. As each column is punched, the card is advanced automatically to the next column. This is similar to the action that takes place on a typewriter as letters are typed on paper. As the card moves from right to left, the columns are punched from left to right.

a. Characteristics.

(1) Card hopper. The card hopper, which holds approximately 500 cards, is located on the upper right side of the machine. The cards are placed in the hopper face forward with the 9 edge down; the front card is fed first. In discussing punched cards we frequently refer to the 9 edge, which is the bottom of the card, and the 12 edge, which is the top of the card. The reason for this is obvious. The numbers on the bottom line are all 9's, and the ones on the top line are considered to be 12's. The cards are uniformly fed, by a sliding pressure plate, from the hopper to the card bed automatically or by depressing the feed key. The first two cards to be punched must be fed by key depression, but all other cards in the hopper may be fed automatically by setting the automatic feed switch.

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Figure 4. Card punch.

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(2) Punching station. Punching is performed at the first of two stations in the card bed through which cards pass from right to left. Normally, to start an operation, two cards are fed into the card bed at the right of the punching station. As the second card is fed in, the first card is automatically registered for card punching; that is, it is positioned at the punching station. While the first card is being punched, the second card waits at the right of the card bed. When column 80 of the first card passes the punching station, the second card is registered at the punching station and the next card in the hopper is fed into the right of the card bed. A single card may be placed in the card bed by hand and registered in punching position by key depression.

(3) Reading station. The reading station, at which cards are read for duplicating, is located approximately the distance of one card to the left of the punching station. Consequently, each card that has been punched passes through the reading station as the next card is being punched. The two cards are moved at the same time, column by column, and information to be duplicated is transferred from the first card to the second card. Punching from one card to another can be controlled, field by field, so that only the desired information is duplicated.

(4) Card stacker. The card stacker, which holds approximately 500 cards, is located on the upper side of the machine on a level with the hopper. After each card passes the reading station it is fed into the stacker, automatically or by key depression. Cards are stacked at an angle, the 12 edge down, with the back of the cards facing the operator. These cards are held in position by a pressure plate. When the cards are removed from the stacker they are in their original sequence.

(5) Main line switch. This switch is located near the top of the stacker. After the main line switch is turned ON, approximately 1 minute must be allowed for the electronic tubes to warm up. When the stacker is full, the switch is turned OFF automatically.

(6) Reading board. A reading board provides ample space for source documents from which cards are punched.

(7) Keyboard. On the keyboard the punching keys and control keys are clearly marked. The home keys are more concave than the other keys to facilitate accurate touch operation. The keyboard is designed so that two keys cannot be pressed at the same time, but one key does not have to rise before another is pressed. The usual numeric keys (as on a typewriter) have been eliminated; instead, a group of dual-purpose keys at the right serve for digit as well as letter punching. This permits numeric punching with the right hand from the home position for letter punching. Punching a digit or a letter with any of the combination keys depends upon the shift of the keyboard.

(8) Spacebar. The spacebar can be depressed at any time to space over a column of the card.

(9) Program unit. The program unit controls automatic skipping, automatic duplicating, and shifting from numeric to alphabetic punching or vice versa. Each of these operations is designed by a specific code punched in a program card. The program card is locked around a program drum and inserted in the machine, where it is read by a sensing mechanism. The drum revolves in step with the movement of the cards past the punching and reading stations so that the program codes control the operations—column by column.

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b. Verifying.

(1) A card verifier (fig 5) is similar to the card punch; however, its main function is to check, rather than to punch, data in a card. A second operator feeds data cards into the hopper and keys in the information from the source document. As the operator keys in the data a metal plunger passes through or senses the punched holes. If the holes are not where they should be, meaning that they do not represent the proper character, then the error is indicated by a notch at the top of each column that is punched incorrectly. If the sensed holes match the correct characters, as keyed in by the operator, a notch is made at the right edge of the card to indicate that the card is correct.

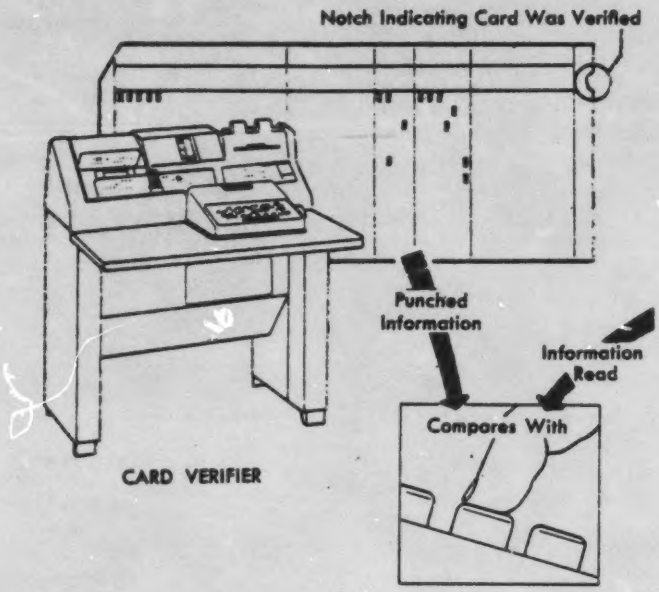
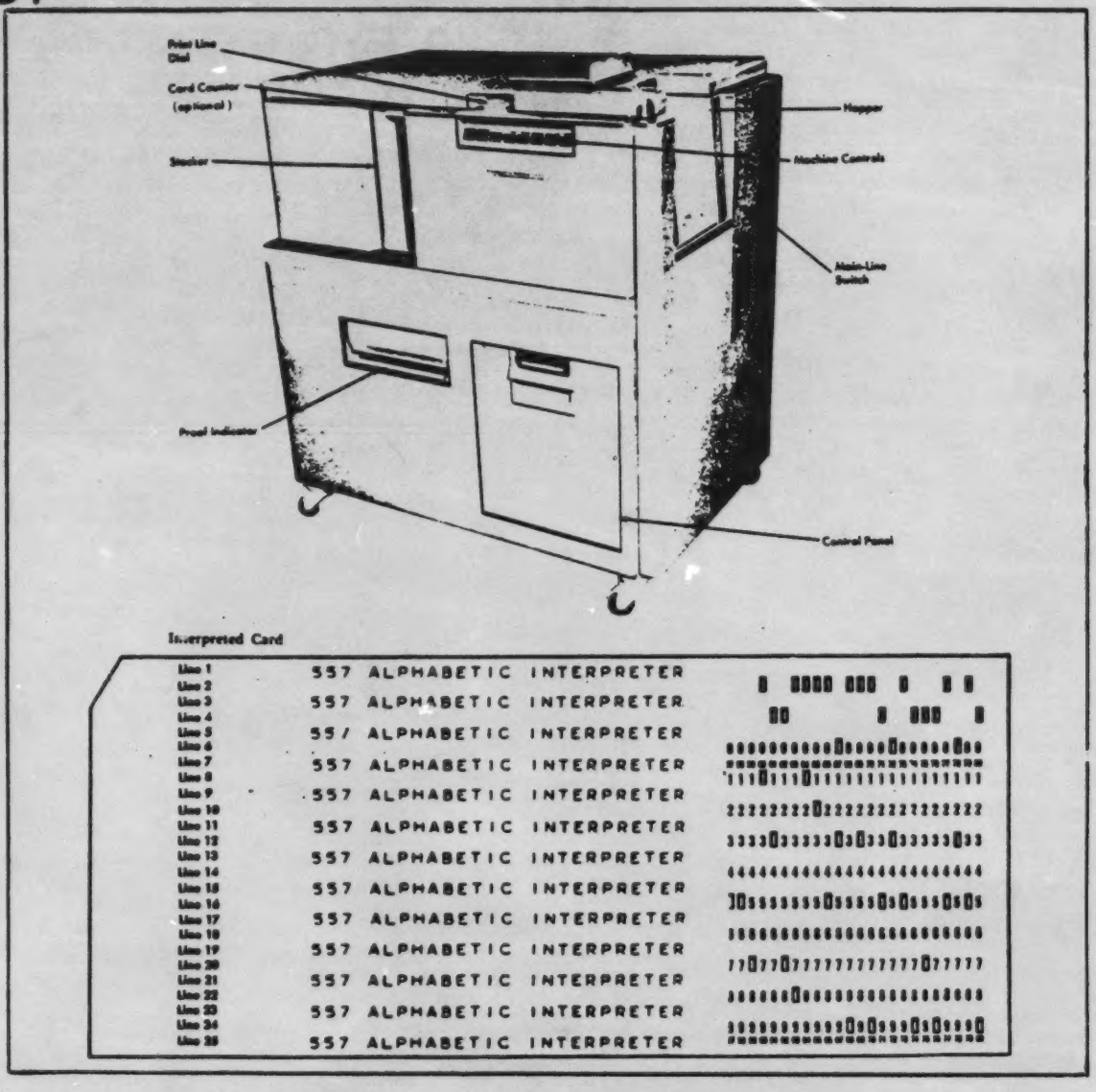


Figure 5. Card verifying.

(2) The time spent in verification illustrates the importance of accurately punched data. If errors are not corrected at this stage they will be present throughout the entire processing cycle. Errors must be corrected as soon as possible.

11. INTERPRETER. Interpreting is the process of converting punched card holes into human language. This is done primarily by sensing alphabetic or numeric data that is punched in a card and printing it on the same card. Duplicated, gang-punched, or otherwise reproduced cards do not always give a visual interpretation of the holes punched into them. To assist the user in interpreting these holes, the cards are placed in the hopper of the interpreter (fig 6). With the proper control panel inserted, each card is read and the desired interpretation is printed at the top of the card. Unlike the card punch, which is capable of printing at the top of each column the meaning of the character it contains, the interpreter prints across the face of the card in specific locations and in larger type than the card punch.


Card Counter (optional)
Stacker
Hopper
Machine Controls
Main Line Switch
Control Panel
Interpreted Card
Line 1 557 ALPHABETIC INTERPRETER
Line 2 557 ALPHABETIC INTERPRETER
Line 3 557 ALPHABETIC INTERPRETER
Line 4 557 ALPHABETIC INTERPRETER
Line 5 557 ALPHABETIC INTERPRETER
Line 6 557 ALPHABETIC INTERPRETER
Line 7 557 ALPHABETIC INTERPRETER
Line 8 557 ALPHABETIC INTERPRETER
Line 9 557 ALPHABETIC INTERPRETER
Line 10 557 ALPHABETIC INTERPRETER
Line 11 557 ALPHABETIC INTERPRETER
Line 12 557 ALPHABETIC INTERPRETER
Line 13 557 ALPHABETIC INTERPRETER
Line 14 557 ALPHABETIC INTERPRETER
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Line 23 557 ALPHABETIC INTERPRETER
Line 24 557 ALPHABETIC INTERPRETER
Line 25 557 ALPHABETIC INTERPRETER

Figure 6. Interpreting (IBM 557 interpreter).

a. Description. An interpreter reads information punched in a card and prints that information at the rate of 100 cards a minute. Although the card has 80 columns for punching purposes, the width of the printed characters used in interpreting allows only 60 characters to be printed across the card. As many as 60 characters can be printed on any one line of 25 different printing positions on each card with a single pass through the machine. These lines are located from the 12 edge to the 9 edge of the card and can be selected by a manually operated printing position dial or by control panel wiring. Flexibility of printing and control is provided through a control panel. Figure 6 illustrates the 25 lines of printing.

b. Main line switch. This switch must be ON for the machine to operate. When this switch is turned ON the running indicator light shows that the machine is ready for use. The light goes off when the machine is feeding cards.

c. Start and stop keys. Card feeding is started by pressing the start key. Pressing this key for three card feed cycles causes automatic operation. The stop key can be pressed at any time to stop card feeding. When the stop key is pressed, cards stop feeding from the hopper; those already in the machine are automatically fed into the stacker.

d. Printing. Interpreted characters, numeric and alphabetic, may be printed across the card according to the setting of the printline dial. The selection of characters to be printed across the card is controlled through the medium of a control panel. When a properly wired control panel is clamped into the receptacle on the front of the machine, it electrically tells the machine which fields of the card to read and where to print the information. Cards usually are designed so that the exact location of the printing is indicated on the form. The printing mechanism consists of 60 type bars, each bar containing 38 printing characters—10 numeric (0 to 9), 26 alphabetic (A to Z), and two special characters. If 60 columns of interpretation are sufficient and all printing is to appear on one line, the operation may be accomplished in one run of the cards through the machine. If it is necessary to interpret more than 60 columns, the cards may be run through the machine several times, using the other 24 printing lines for the additional interpretation.

12. SORTER. Sorting documents into sections or groups by hand has always been a time-consuming and tedious operation that frequently results in errors. Similarly, finding needed documents in a file of records can be a slow and inaccurate process. These sorting and selecting functions usually precede the preparation of various reports. Reports must be accurate and timely since they form the basis for administrative action. One of the greatest advantages derived from the use of punched card records is the ability to sort and select with a machine known as a sorter (fig 7). This is the machine that performs the second step in machine accounting. It is here that the separate groups of transaction cards are filed in sequence.

a. Description. A card feed hopper is located at the upper right corner of the machine. This hopper has a capacity of approximately 800 cards and is the receptacle into which an operator places the cards to be sorted. To the left of the hopper is a glass top under which are 13 compartments, or pockets, to receive the cards after they have passed through the machine. The pockets are arranged from left to right in the following manner: 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, 11, 12, and R. Each pocket corresponds to one of the 12 punching positions in a card column. The R (reject) pocket receives cards that are unpunched in the column being sorted. Cards pass through the machine at the rate of a thousand cards a minute. The cards are placed in the feed hopper face down with the 9 edge toward the machine. The throat allows only one card to be fed at a time. When the start key is depressed, the cards are automatically fed from the bottom of the stack by a card knife. They advance between the sorting brush and the metal roller, thereby closing an electric circuit. A chute blade corresponding to the punched hole is electrically opened and the card is directed between the chute blade and the feed rolls into the proper pocket. For example, all cards punched "1" in the column being sorted will fall into the 1 pocket of the machine and all cards punched "2" will fall into the 2 pocket. If no punching appears in the column, the card will fall into the reject pocket. Each pocket of the sorter is equipped with an automatic stop lever that stops the machine when any pocket is filled with cards. The cards must be removed and the start key depressed before the operation can be resumed.

b. Sight checking. As the cards are removed from the pockets the sorting must be checked. This is done by joggling the cards into perfect alinement as they are removed from each pocket, holding them in front of a light, and looking through the hole corresponding to the pocket from which they were removed. If the cards have been properly sorted, the holes create a tunnel through which light may be seen. When the digit in question is not punched in any card of the group being checked, it is impossible to sight check the position. This indicates that one or more cards have been sorted improperly. These must be located, removed, and refiled in their proper places.

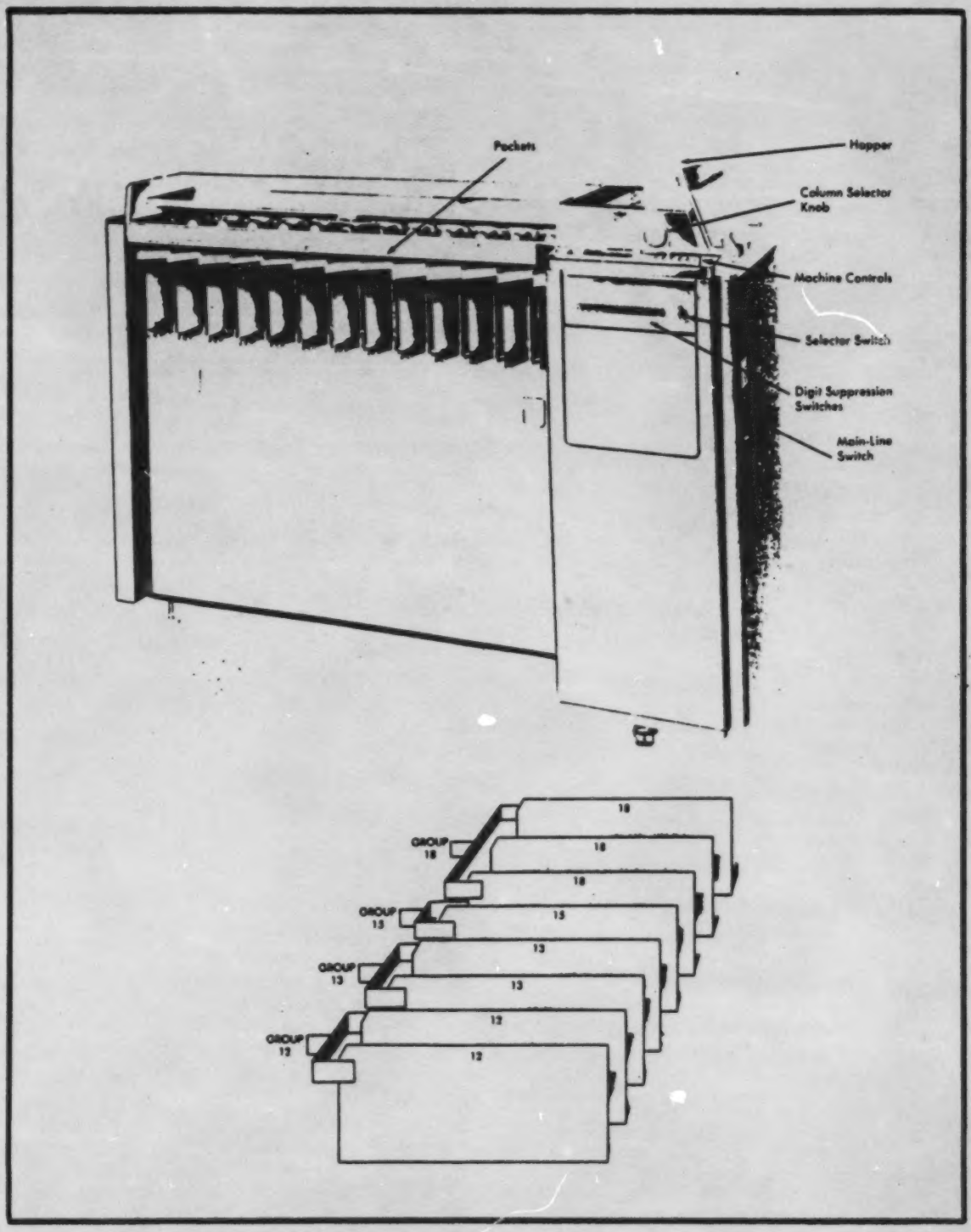

Figure 7. Sorting (IBM 83 sorter).

13. COLLATOR. One of the greatest problems in any manual system is withdrawing and filing documents according to a predetermined pattern. Once the pattern is established, the filing must be done accordingly so that the documents may be located readily when needed. This pattern is essential not only when refiling documents removed from the file but also when filing documents that are additions to the file. Where punched card records are in use, this is still a problem. The sorter is capable of interfiling cards on a limited scale, provided that the merging field is in the same location in each card. However, two decks of cards may have the same data punched in different fields. To merge these two decks by using the sorter would require repunching one deck to make it conform to the format of the other deck. One advantage of the collator is that it can merge the two decks even though the desired data is punched in different columns.

a. Description. A collator (fig 8) is equipped with two input hoppers. The upright file hopper is the primary feed holding up to 3,600 cards. The other hopper is the secondary feed which holds up to 1,200 cards to be filed. In the center of the front of the machine are five stackers (collator pockets) numbered from right to left—1, 2, 3, 4, and 5.

b. Operations. A collator performs many operations. In fact, it is sometimes referred to as an automatic file clerk. We could not hope to describe all that the collator can do; however, following are a few of the more basic functions and applications of this machine.

(1) Sequence checking. Sequence checking is the operation by which the present sequence of a file of cards is automatically checked. This operation may be performed as an independent function or in combination with other operations. Sequence checking can be performed either in ascending or descending order. Usually, however, we sequence check cards in ascending order, from low to high.

(2) Merging. Merging is combining two sets of punched cards into one set in a certain sequence. Both files of cards must be in sequence before they can be merged. This function makes possible automatic filing of any cards into an existing file of cards. It is a fast method of sorting when placing related cards together.

(3) Matching. Matching is checking the agreement between two sets of cards. Groups of cards in one file are compared with similar cards in another. A second file of unmatched cards or groups of cards in either file may be selected or separated from the files. This function is frequently performed in conjunction with merging, thereby performing an operation called match-merging.

14. REPRODUCING PUNCH. One characteristic of manual records is monotonous repetition. Records made on the same day must be dated identically. Records made at the same source must bear identical information as to location. Similarly, information used at one unit may be needed at another, often requiring duplication of the same basic records. In some cases, partial changes to the original records have to be made continually to keep the records up to date. For many years the only method of punching holes in IBM cards was by depressing the keys of a manually operated card punch. Information had to be read by the eye, either from the original document or some records on the card itself. The development of the duplication feature of the card punch eliminated the manual punching of repetitive data. While this feature is useful as an aid in keypunching, it does not satisfactorily meet requirements when entire files of cards have to be partially changed or duplicated for one reason or another. These functions, as well as punching total or summary cards from reports prepared by accounting machines, are performed automatically by a machine known as the reproducing punch.

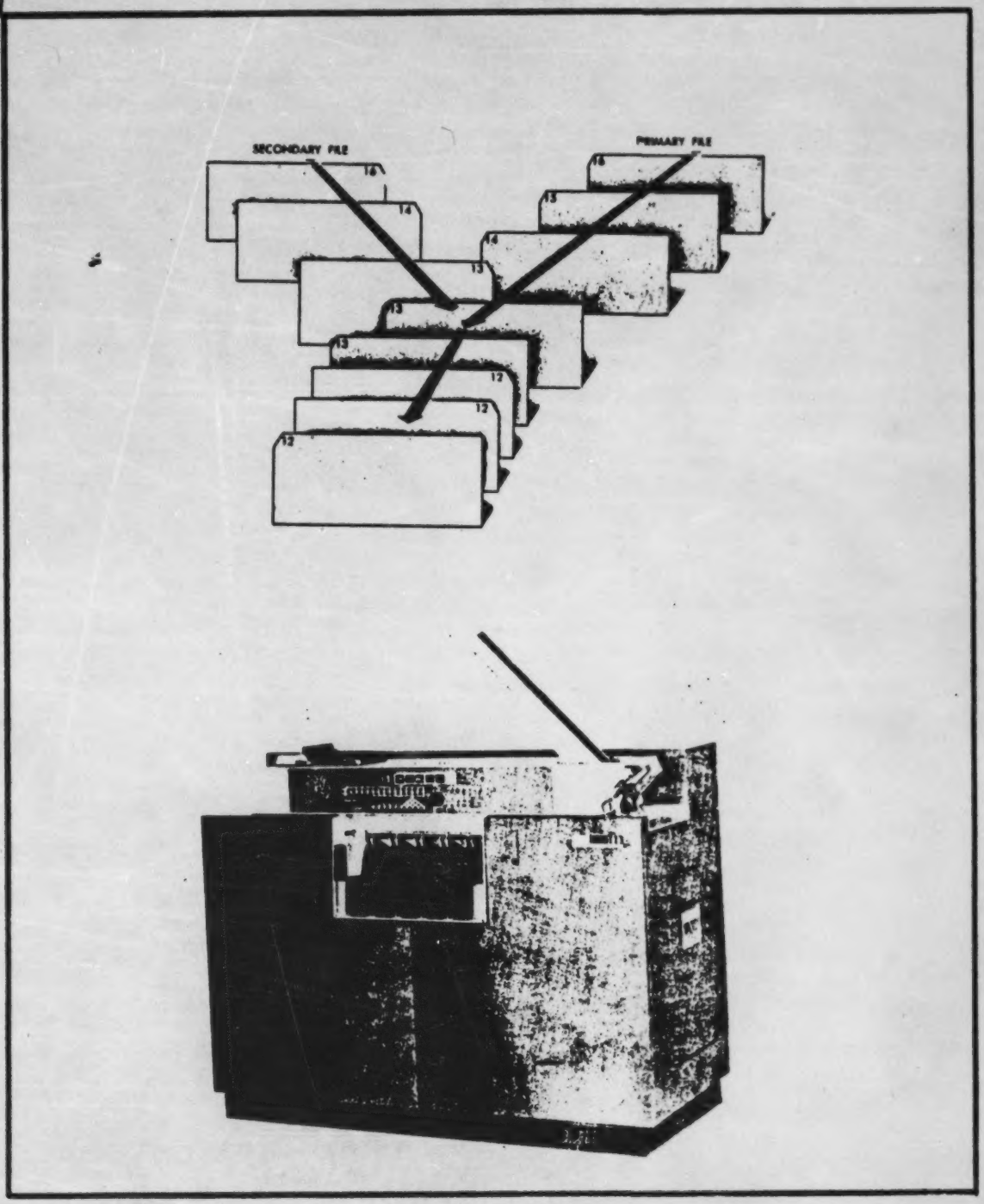

Figure 8. Collating (IBM 188 collator).

a. Description. This document originating machine (fig 9) has two card feed hoppers: a read-unit feed on the left and a punch-unit feed on the right. Each feed has a capacity of approximately 800 cards. One unit of the machine reads previously punched cards while the other unit punches the blank cards that are to become duplicates of the originals.

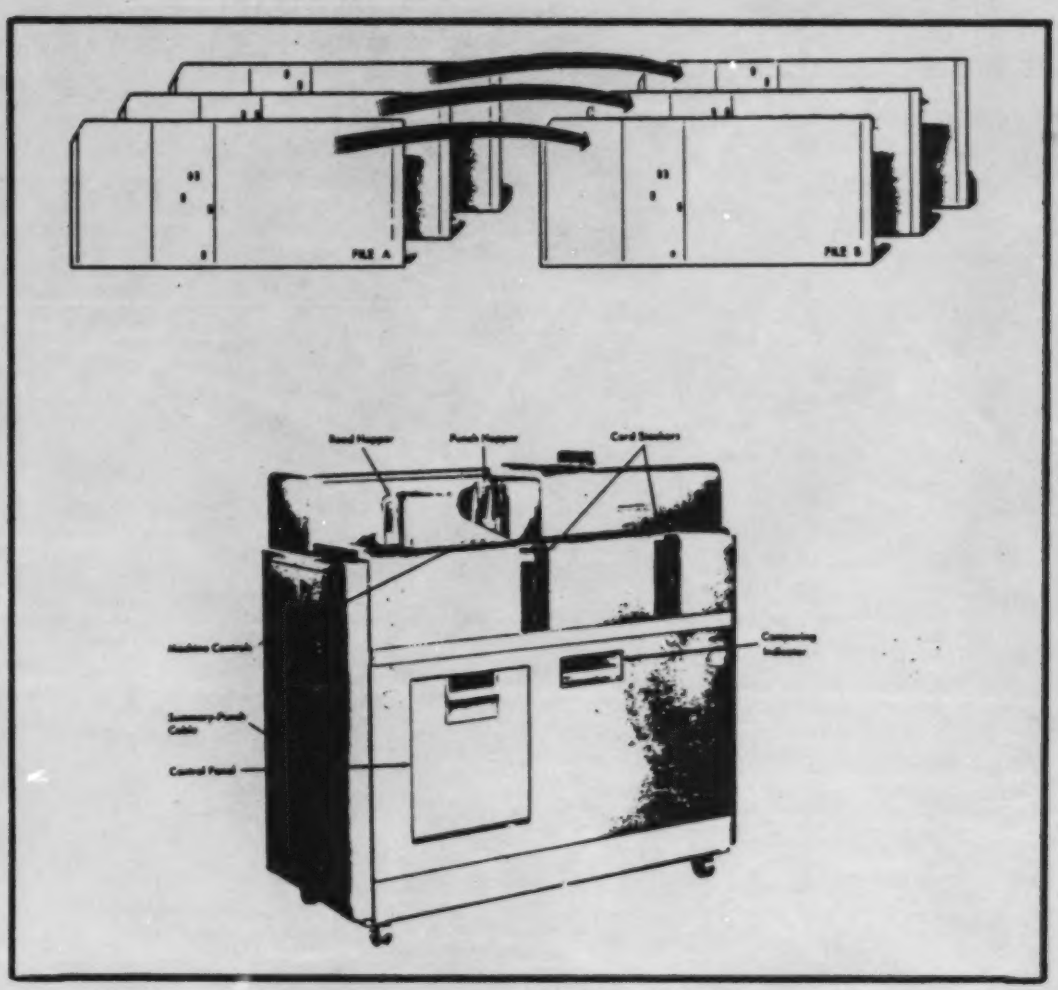

Figure 9. Reproducing punch (IBM 519 document originating machine).

b. Operations. The reproducing punch can perform many operations and functions in the field of punched card accounting. Two of the most common operations are gang punching and reproducing.

(1) Gang punching is automatically copying punched information from a master card into one or more detail cards that follow it. In single master card gang punching, one master card precedes all detail cards to be punched with the same information. When information changes from one group of cards to the next, the intersperse gang punching method is used. A master card always precedes each group of detail cards. Information in the master card is automatically selected for punching into the following detail cards until a new master card is read. The punching pattern then changes to conform to the new master

card. The punching in this operation takes place on the punch side of the machine. To check the work of the machine for single master card gang punching, the first card is compared or sight checked with the last card. In interspersed gang punching, the cards are punched in the punch unit and then verified in the read unit.

(2) Reproducing from one card to another is like copying from one record to another. Information from one set of punched source cards is automatically punched into another set of cards. The two sets of cards are fed through the machine at the same time. In this case, the original deck of cards is placed in the read unit and a blank deck of cards is placed in the punch unit. Information from each source card in the read unit is transcribed from the card (as it passes through the read side of the machine) to a new card on the punch side of the machine, duplicating the information from the old cards to the new ones. The comparing feature of the machine checks for agreement between originals and reproductions during the same pass through the machine and differences are automatically pointed out by the comparing indicator.

15. CALCULATOR.

a. Calculating is computing a result by adding, subtracting, multiplying, or dividing. A calculator performs these functions at millisecond (one-thousandth of a second) speed on factors punched in punched cards. The results of these calculations can be punched into the same card from which the factors are read; or, if desired, these results can be punched into a subsequent or trailer card or cards. A calculator (fig 10) contains both a punch unit and calculating unit. The use of solid state (transistor and diode) components makes this a small, compact unit that operates on 115-volt current and does not require any special air conditioning.

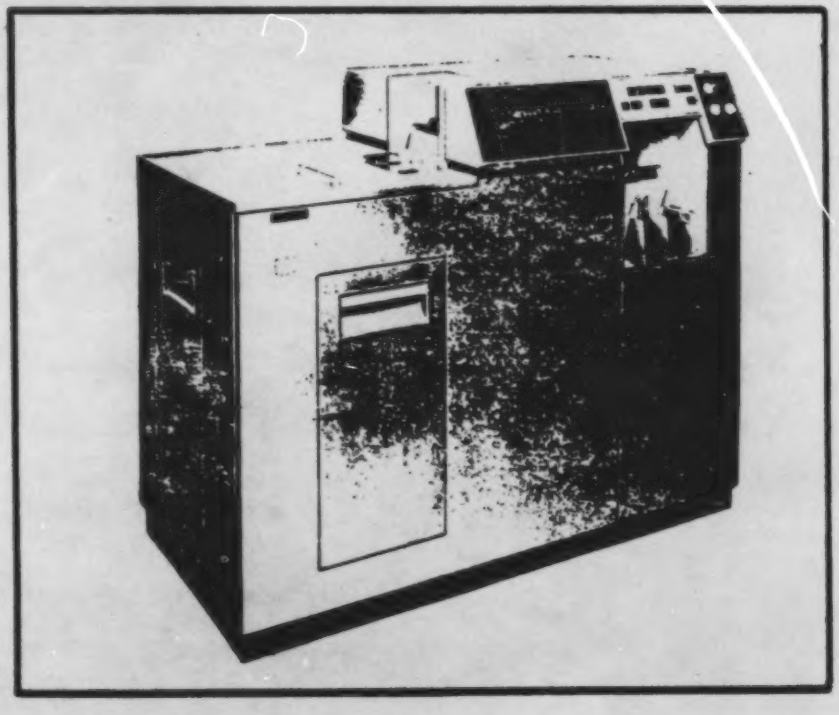

Figure 10. Calculating (IBM 609 calculator).

b. A calculator uses two control panels or a single two-section control panel, depending upon the model. All card reading or card punching functions are wired on the upper punch section, and all calculator functions are wired on the lower calculate section of the control panel. This calculator performs all arithmetic operations at a speed of 200 cards a minute, allowing 110 milliseconds for calculating. To perform these operations at such a tremendous speed, the calculator uses internal magnetic core storage. Magnetic core storage is used primarily in computers and will be explained in detail in later instruction. Here we need only know that it enables the calculator to record, retain, and later calculate and punch out the calculated information at speeds far in excess of any other punched card machine.

16. ACCOUNTING MACHINE. If management is to operate at top efficiency it must be kept constantly informed by reliable, up-to-date information about such things as material, sales, inventories, payroll, and production. This information is prepared for management in the form of reports and analyses, which become the basis for administrative actions. Many computations must be made, checked, and summarized before the data can be presented in report form. Because of the time required, manual methods often fall far short of meeting management's requirements. With the basic information in punched cards, management reports can be prepared with the needed speed and accuracy. The machine accounting principle consists of three basic steps: first, information wirtten on source documents is transcribed to punched cards; second, the punched cards are arranged by the sorter in sequence desired; and third, printed reports are prepared automatically by accounting machines which read the holes in the cards and print the reports. This third step is called summarizing and the machine used to summarize is the accounting machine (fig 11).

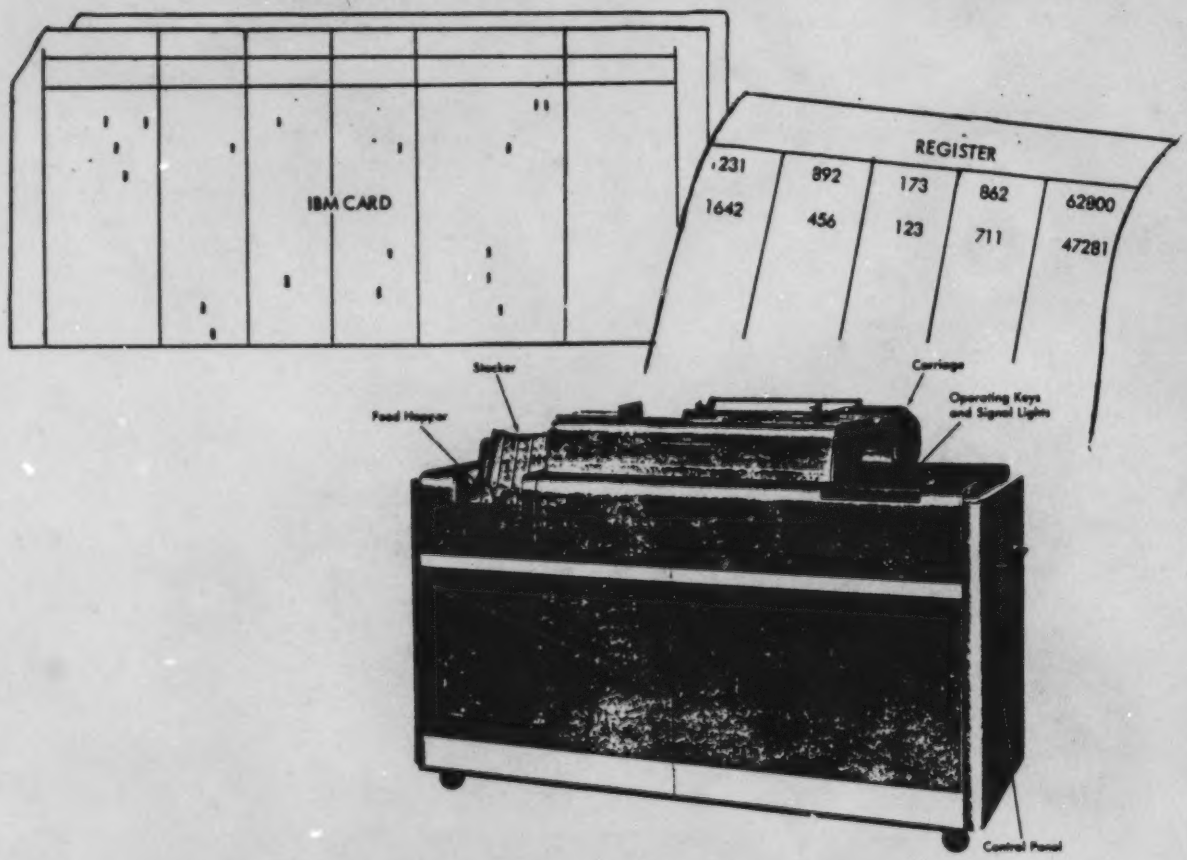

Figure 11. Summarizing (IBM 407 accounting machine).

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a. Description. An accounting machine operates automatically in both feeding the cards and printing the results. The information punched in the card can be read, added, subtracted, compared, or selected, according to the requirements of the report. The machine can do this at the rate of 150 cards a minute. The machine prints information from 120 print wheels. Each print wheel has 47 different characters: all the letters of the alphabet, all the numbers, and 11 special characters. The machine is completely flexible in arranging the printed data on the form, and summary cards can be punched simultaneously with the preparation of reports.

b. Operations.

(1) Detail printing. This operation, printing information from each card as it passes through the machine, is used to prepare reports that show complete details about each transaction. During this listing operation the machine adds, subtracts, and prints computations of totals.

(2) Group printing. In this operation the information on each card is accumulated automatically but not printed. The only information printed is data needed to identify a group of cards for which totals have been accumulated and the total. Therefore, in group printing, we obtain results by groups of cards rather than for each single card.

(3) Programing. This is the function by which the machine can distinguish the cards of one group from those of another. There are three classifications of program control: major, intermediate, and minor. For example, if automatic totals are desired by States, counties, and cities, States would be the major group, counties would be the intermediate group, and cities would be the minor group.

(4) Summary punching. This is recording summary, or total, information into cards in the form of punched holes. For example, when an inventory report is prepared on an accounting machine it can be set up to show, by each type of material, the balance on hand at the first of the month, the receipts and issues during the month, and the balance on hand at the end of the month. As totals are printed by each type of product on the accounting machine, the information can be automatically punched into summary cards on the reproducing punch. The totals are transmitted from the accounting machine to the reproducing summary punch through the summary punch cable that connects both machines. Summary punching may be done either in a detail or group printing operation. All information to be summary punched is controlled by both the control panel in the accounting machine and the control panel in the reproducing summary punch.

17. OTHER PUNCHED CARD MACHINES. In addition to these basic machines, there are two other examples of punched card equipment that deserve consideration.

a. Data transceiver. This machine (fig 12) reads data punched in cards for transmission over leased telephone lines or telegraph circuits to a second transceiver, which simultaneously punches the information into a card. One unit can perform either reading or punching functions.

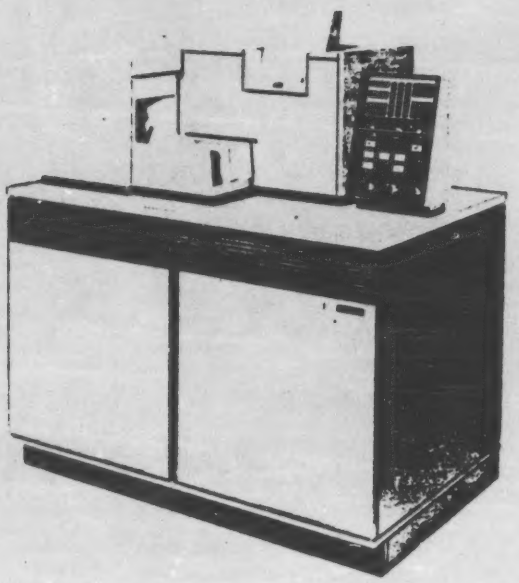


Figure 12. Data transceiver.

b. Electronic statistical machine. This machine (fig 13) combines in one unit the functions of sorting, sequence checking, selecting, editing, counting, accumulating, and printing. It is designed for high speed classifying and counting and for preparing printed statistical reports.

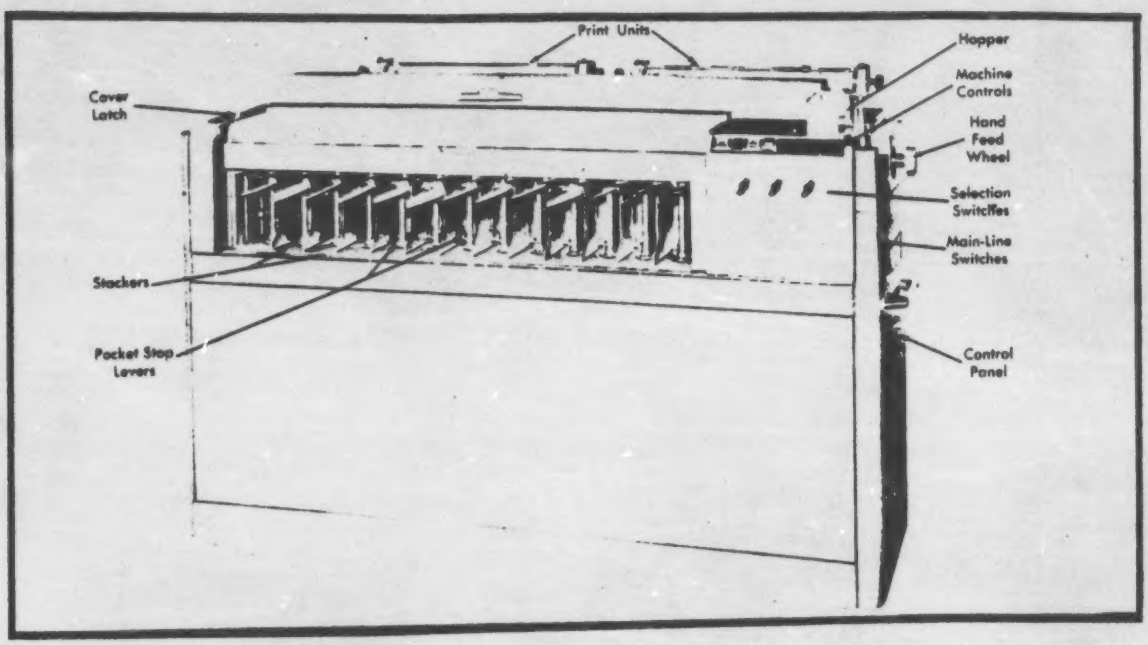
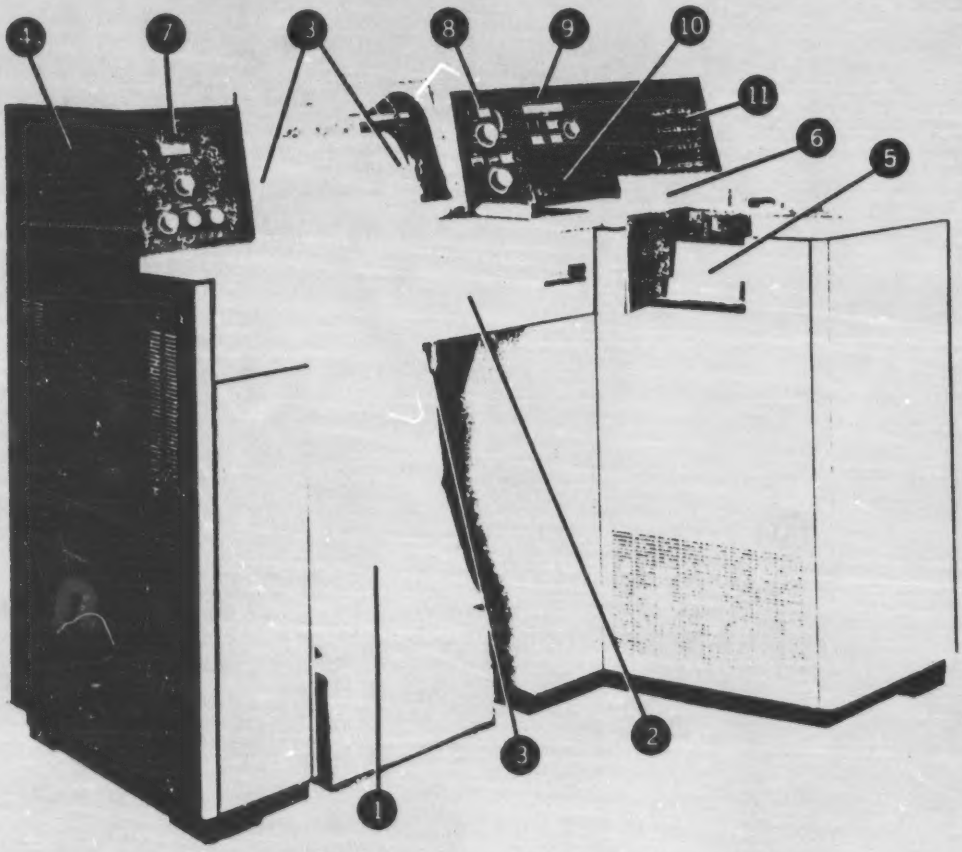


Figure 13. Electronic statistical machine.

c. Card processor.

(1) One type of punched card equipment that is increasing in popularity and use throughout the Army is the UNIVAC 1005 card processor (fig 14). This piece of punched card equipment is actually a small computer. Unlike most computers, however, it uses punched cards as its primary input medium.

(2) The card processor performs the same basic functions as the accounting machine, reproducing punch, and calculator in that it reads data from punched cards, processes this data, duplicates punched cards, and prepares printed reports. However, since it employs electronic instead of mechanical circuitry, it can perform the functions more rapidly than those machines.



LEFT-FRONT VIEW OF PROCESSOR

1 - PAPER FORM
2 - CARRIAGE
3 - TRACTORS
4 - ACCESS DOOR TO FORM CONTROL TAPE AND LINE SPACING SWITCH
5 - INPUT MAGAZINE
6 - CARD STACKER
7 - CONTROL PANEL 1
8 - CONTROL PANEL 2
9 - CENTRAL CONTROL PANEL
10 - TEST SWITCH PANEL
11 - DISPLAY PANEL
(CARD PUNCH NOT SHOWN)

Figure 14. UNIVAC 1005 card processor.

SECTION IV. BASIC CONSIDERATIONS OF REPORT DESIGNING

18. GENERAL.

a. There are many factors that must be considered in designing punched card records. Because of course limitations, we will discuss only the most important factors. Proper design and layout of punched card records increase the speed and accuracy of card punching and verification.

b. Figure 15 is a "Multiple Card Layout Form" on which new cards can be designed. This form provides for the designing of six different cards. By merely drawing a line following one or more spaces and labeling the space created by the line with the name of the field of data which he wants recorded here, the analyst can quickly design several punched cards.

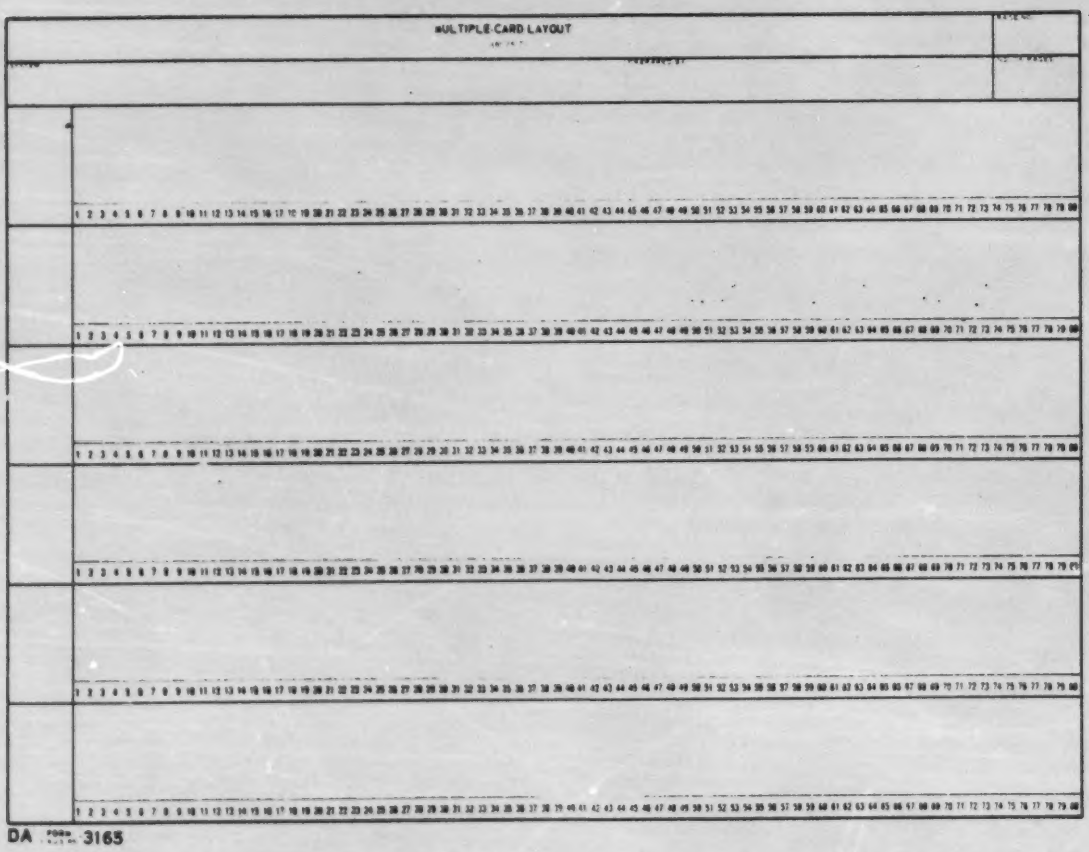


Figure 15. Multiple-card layout form.

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19. CARD DESIGN AND LAYOUT.

a. Types of cards.

(1) TRANSCRIPT CARDS are punched from information previously recorded on other documents. An example of this is DA Form 2765, REQUEST FOR ISSUE OR TURN-IN, which is punched from DA Form 2765-1, MANUAL REQUEST FOR ISSUE OR TURN-IN.

(2) DUAL CARDS are punched from information previously written on the cards themselves. Thus, they serve a dual purpose as both source document and processing medium. An example of this is the prepunched DA Form 2765 provided to the user. The user uses these cards to request his supplies. Any information that he places on the prepunched DA Form 2765 is punched directly on the same card by the support unit.

(3) MARK-SENSED CARDS are automatically punched from electrographic pencil marks that are recorded in mark-sensing positions on the face of the cards. Certain weekly attendance and meter reading cards are of this type. They are marked by an employee on the job and sent to the machine room where the mark-sense data are machine read and punched into the same or different card for processing.

(4) OUTPUT CARDS are automatically machine created as a result of processing disk storage records, tape records, or other cards. Examples include summary, balance forward, updated file, and exception and certain detail cards. Some of these undergo additional processing for report preparation, while others replace the corresponding but outdated cards in a file.

(5) SPECIAL CARDS are used with the IBM-PORT-A-PUNCH to enable on-the-spot punching of data. Punching positions of those columns that are to be used for recording data are prescored; the holes are created by punching out the prescored chips with a special instrument.

b. Determining card data.

(1) The first step in card design requires a study of the final report that is to be printed from the card and a listing of data needed for it. Next the procedure is studied and any data needed for processing that are not also needed for the report are added to the same listing. Provision must be made for recording in the card all data that are listed unless they are calculated, emitted, or summarized.

(2) A check should be made that the necessary reference data are included on the listing. Reference data should be sufficient to:

(a) Identify the transaction with the original source document from which it was created.

(b) Indicate the date on which the transaction occurred.

(c) Designate a person, place, or item responsible for or involved in the transaction.

(3) The amount of reference data that are necessary is determined by the use to which the cards will be put and the reports that will be written from them. Care should be taken to avoid duplicate or unnecessary reference data.

c. Determining field size.

(1) The number of columns required to record each type of information should be determined and added to the list. For codes, dates, Federal stock numbers, unit identify codes, etc, this is determined by the largest single number to be recorded. Thus, 11 columns are reserved for Federal stock numbers.

(2) With quantity and amount fields, the problem becomes more difficult. In the first place, the space needed to record the largest amount may not be known; in the second place, if the largest amount is known, its chances of occurring may be rare.

(3) It is, therefore, a good plan to provide for all except those rare cases and to handle them by punching extra cards. If, for example, the seven-digit amount $67,265.80 is a rare case, it may be recorded in a six-column field by punching six cards of $9,999.99 and one card for $7,265.86 (or any combination of six-digit numbers totaling $67,265.80). In designing summary and balance forward cards, however, the amount fields must be made large enough to accommodate the summary totals.

(4) For punching names 20 columns are generally sufficient; this should be carefully checked, however, on each individual job. A study of the number of columns required for recording names and addresses reveals that 95 percent of names of individuals can be recorded in 18 columns or less; that 95 percent of names of companies requires 20 columns or less; that 90 percent of street addresses requires 18 columns or less; and that 99 percent of cities and states (abbreviated) requires 20 columns or less.

d. Determine data sequence.

(1) There are four major considerations in determining a card's data sequence. In order of importance these are:

(a) The location of identical data in other cards with which the new one will be processed.

(b) The sequence of data on the source document from which the card will be punched.

(c) The machines and/or programs to be used during processing.

(d) The manual operations in which the card will be used.

(2) The effect upon sequence of machines and/or programs, as well as manual operations and the location of interpreted information, can be indicated in the remarks column. The completed card design worksheet is very useful in later design operations.

(3) A given field of information in the new card should be placed in the same columns previously assigned to it in the other cards. This insures that sorting and controlling can be accomplished when the cards are processed together; it also facilitates control panel wiring and programing. In cases where summary cards are designed to accommodate year-to-date figures or balance forward amounts that by their nature must be larger than corresponding fields in the detail transaction cards, the amount fields in both should be alined as nearly as possible.

(4) Examples of different cards that are processed together include a master inventory card used with transaction cards to update the master inventory.

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(5) Card punching, being a manual operation, is subject to the greatest variation in production rate. Anything that simplifies it will tend to insure a faster and more accurate operation. Data should be punched into a card in the same order in which they are normally read. If the data sequence on the card is considerably different from that on the source document, it may be necessary to redesign the source document.

(6) Cards can be designed to take full advantage of both machine characteristics and processing techniques. Some of the major ones are discussed below.

(a) Card punches. In designing a dual card it is better to locate the handwritten data on the left side of the card and the punched data on the right. This is insurance against having handwritten data under the card pressure lever when it is being read for punching.

(b) Computers. Computer characteristics should be investigated to determine whether the card's design will affect processing speed. With many computers the ability to move and process blocks of data without rearrangement will facilitate programing and increase processing speed.

(c) Control panel wiring. In installations where control panels are not permanently wired, the accuracy and speed of frequent wiring operations are improved if the input card's data sequence is similar to that for reading, punching, and printing.

(d) Manual card handling. If data are to be punched and printed on the 26 printing card punch, any information to be checked visually should be placed near the right or left end of the card. This makes it easier to fan and check a group of cards. If data will be read from cards that are sitting in a file, make certain that the reference data are positioned so that they can be easily seen.

e. Drawing the layout.

(1) In drawing the card layout there are a number of points to be considered. The value of each should be determined by the card being designed and the application in which it will be used.

(2) All field headings should be explicit and ambiguous abbreviations avoided. Headings for written information should be such that they force writing into the desired location. Make certain that adequate space has been allowed for this writing.

(3) If a dual card is being designed, the right-hand side of each area or box containing handwritten data should be at least five card columns to the left of the field in which it is to be punched. This prevents the data from being obscured when it is time to punch it.

(4) When designing a dual card, use one area of the card exclusively for handwritten data so that they will not be obliterated by punching. If there must be an overlap of handwritten and punched data, use the overlap for recording descriptive information, which can be easily reconstructed.

(5) Any information, handwritten or printed, that is to be visually checked should be placed near the right or left end of the card so that it can be seen easily when the cards are fanned.

(6) Fields for recording mark-sensing marks should be placed on the right-hand side of the card so that the card can be held and marked easily. Since marking positions are physically located above punching positions, these fields may overlap punched fields.

(7) Corner cuts can be used effectively to distinguish card types during processing and clerical operations. However, it is not recommended that the lower left corner cut be used on cards that are to be processed on the IBM 24 card punch and machines with similar type feeds. In printing headings on the layout, indicate their relative size and any punctuation that is needed for interpreted and/or handwritten data.

APPENDIX I

REFERENCES

USAAGS MEMO 90-2	Principles of Punched Card Data Processing	Aug 71
USAAGS MEMO 96-3	Input and Output Requirements and Design	Jul 71

APPENDIX II

PUNCHED CARD GLOSSARY

ACCUMULATING: Adding or subtracting in a counter to obtain a total.

AUXILIARY COUNTER: A device for counting cards passing through the machine.

BRUSH: An electrical conductor for reading information from a punched card. Normally, each brush has a corresponding hub on the control panel.

CABLE: A group of wires bound together and used to connect machine units (for example, summary-punch cable).

CARD BED: A flat plate over which cards travel from hopper to stacker.

CARD FEED: The path of the card from the hopper to the stacker.

CARD GAGE: A metal plate, precisely inscribed with all punches of an 80-column card, used to check the accuracy of punching registration.

CARD JAM: A pileup of cards in a machine.

CARD LEVEL: A lever for electrically detecting the presence of a card along the card path.

CARD WEIGHT: A weight placed on the cards in the hopper to permit feeding the last cards.

CARRIAGE: A device on the accounting machine for controlled feeding of continuous forms.

CHANNEL: One of 12 specific positions on the carriage tape to govern skipping of forms.

CHIP BOX: A container that collects the punched-out chips, or chads, from the punches.

CHUTE BLADES: Metal strips that guide a card along the card path to the selected pocket.

COLLATING: Arranging two files of cards into a single file according to a predetermined pattern.

COLUMN INDICATOR: The pointer showing the column to be punched or read in a card punch, verifier, or sorter.

COLUMN SELECTOR: A device for positioning the sort brush on a specific column.

COMPARING: Examining two fields in the same or different cards to see if the punching checked is the same.

CONTINUOUS FORMS: Paper or card forms attached for continuous feeding in the accounting machine carriage.

CONTROL PANEL: The demountable panel containing the external wiring to govern machine operations.

CONTROL PUNCH: A punched hole (usually the X or 12 punch) for controlling machine operation, normally by selectors.

CORNER CUT: A diagonal cut at the corner of a card as one means of easy identification (for example, master or detail cards) by sight or by a special rail brush.

CROSSFOOTING: Accumulating numbers in different fields in the same card.

CYCLE: A complete series of operations

at the end of which the entire series can be repeated.

DECK, TEST DECK: A set of cards representative of all operations performed in a particular application. Used to test control-panel wiring and machine operation.

DETAIL PRINTING (LISTING): Printing information from each card passing through the machine.

EDITING: Checking cards for accuracy of punching, counting, or sorting according to a specific pattern.

EJECTION: Movement of a card from the card bed to a stacker.

EMITTING: Originating digits, letters, and special characters electrically within the machine rather than from the punched card.

FANNING THE CARDS: The operation for removing particles lodged between cards and for eliminating static charges causing cards to stick together. Grasp one end of the cards securely, draw the other end back, and allow a few cards at a time to "fan" to the normal position.

FEED KNIFE: The device for feeding cards from the hopper into the machine.

FEED ROLLERS: The rollers that transport a card along the card feed from hopper to stacker.

FIELD: A column or group of columns of a punched card allocated for punching specified information.

FORM STOP: A device for sensing when the last continuous form feeds into an accounting machine.

FORM THICKNESS: The distance between the platen and print unit in an accounting machine. This distance is adjustable to accommodate forms of various thicknesses.

GANG PUNCHING: Punching information read from a master card into the following detail cards. Each card then serves as the master card for the succeeding card.

GROUP INDICATION: Printed information identifying a group.

GROUP PRINTING (TABULATING): Printing group totals and group indication as cards pass through an accounting machine.

HEADING CARDS: Cards punched with significant information used to print headings on forms such as invoices or checks.

HIGH ORDER: The left, or high, position of a number.

HOME KEYS: The position from which the fingers operate in the touch system of keypunching.

HOPPER: The receptacle for holding cards to be fed into a machine.

INTERLOCK: A means of preventing machine operation until required mechanical or electrical conditions are met.

INTERPRETING: Printing information on the same card in which it is punched.

INVERTED FORM: A form (for example, remittance statement, check voucher) on which the body information is printed first, followed by heading information and special instructions.

JOGGLE: To aline a deck of cards by jostling them against a plane surface.

KEYBOARD LOCKING: An interlocking of a keyboard because of improper operation or keying.

LACING: Extra multiple punching in a card column, giving the appearance of lacework.

LOW ORDER: The right, or low, position of a number.

MARK SENSING: Punching information marked on punched cards with an electrographic pencil.

MASTER CARD: The first card of a group containing fixed or indicative information for that group (for example, gang punch master card).

MATCHING: Checking two files to see that there is a corresponding card or group of cards in each file.

MERGING: Combining two files, already in sequence, into a single file.

NEEDLE CHECKING: Verifying that all cards in a deck contain the same punch in a given column. The prod or needle, pushed through the punched hole, stops at a card containing a different punch.

OFF-PUNCHING: Punching not properly positioned in a card. Use a card gage frequently to check punching registration.

OFFSETTING: Stacking cards slightly out of the normal stacking position for easy identification.

OVERFLOW: The carriage operation ejecting one fully printed form to continue printing on the next. Also, exceeding the capacity of a counter.

OVERPUNCHES: Punches (usually control punches) over the significant digits in a column.

PIN-FEED PLATEN: A platen device for feeding marginally punched continuous forms.

PLATEN: The hard rubber roller providing a solid backing for the paper at the printing position.

POCKETS: Receptacles (stackers) for receiving cards from the card feed in a multiple-stacker machine (for example, sorter, collator).

PRINT POSITION DIAL, KNOB: The device in an interpreter for controlling the location of the printing line.

PRINT WHEELS: Wheels, embossed with letters, digits, and special characters, for printing on forms.

PROGRAM CARD: A punched card with specific coding, placed around a program drum to control automatic operations in a card punch and verifier.

PROGRAM DRUM: The card-controlled mechanism on a card punch or verifier for controlling the automatic operations (for example, skipping, duplicating).

PROGRAMING: Establishing a sequence of operations to be performed in processing data.

PUNCH: A mechanism to punch holes in a card.

PUNCH FEED: In automatic punches, the card-feed unit containing the punching mechanism.

PUNCH STATION: The position in the card feed at which punching occurs.

READ FEED: In automatic punches, the card feed containing the reproducing brushes.

READ STATION: The position in the card feed at which reading occurs.

REGISTRATION: The position of punched holes in a punched card. Using the card

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gage, check registration daily and before every major operation to insure accuracy.

REPRODUCING: Copying punched information from one deck of cards into another.

RESTORE: To clear or return a unit to its normal starting position (for example, comparing unit or carriage tape).

ROLLING THE KEYS: The rapid keying operation of pressing the second key before the first is fully released.

RUNOUT: Moving the last cards in the machine to the stacker.

SCANNING POSITION: That position along the card bed or forms path at which the card or form can be fully viewed.

SCORED CARDS: Punched cards that have been partially precut for detaching stubs.

SELECTING: Removing cards from a file, or processing cards according to predetermined conditions.

SEQUENCE CHECKING: Checking cards to insure that they are all in ascending (or descending) order.

SHORT CARD: A punched card of less than 80 columns.

SIGHT CHECKING: Examining a group of cards for identical punching by viewing a light source through the punched holes.

SINGLE SHEET FORM: Forms inserted individually in a carriage for printing.

SKIP BAR: A bar containing inserts or cuts that determine where a punch carriage stops under the punches.

SORTING: Arranging cards in a predetermined sequence according to the punching in the card.

STACKER: A receptacle for receiving cards fed through a machine.

STATION: Any position along a card feed at which a card is processed (for example, reading station, punch station).

STRIPE: A narrow band of a different color across a card for identification.

SUMMARY PUNCHING: Punching summary or total information in cards automatically while printing a report or while calculating.

THROAT, THROAT KNIFE: The opening from the hopper into the machine. A throat knife permits only one form to be fed at a time.

TOGGLE SWITCH: A manually operated switch.

TRAILER CARD: A card placed at the end of a group to serve as a summary or overflow card.

TRANSCRIBING: Printing on one card information that has been punched into another card.

TRAY: A file drawer.

TYPEBARS: A movable bar containing letters, digits, and special characters for printing. A demountable typebar is one that can be readily removed by the operator and replaced with a different typebar.

UNDERPUNCHES: The low punches in a card column (usually the digit punches under zone punching).

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X BRUSHES: Adjustable reading brushes for sensing control punches.

X PANEL: A small panel for connecting the X brushes to the main control panel.

X PUNCHES: See CONTROL PUNCHES.

ZONE PUNCHES: Punches in the 12, X, or 0 positions of a card column, used in combination with digit punches 1 through 9 to code alphabetic and special characters.

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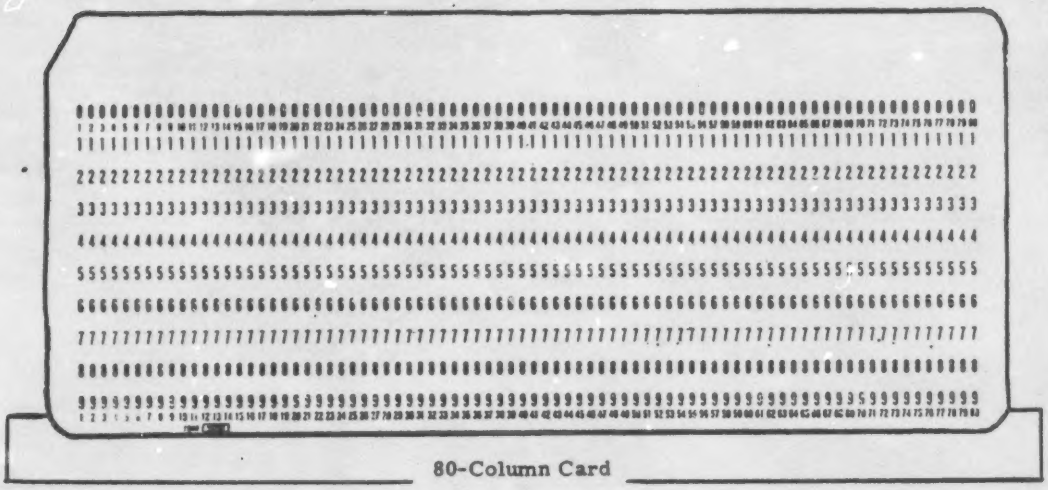
APPENDIX III

HOW TO INTERPRET PUNCHED CARDS

1. Below is an example of the 80-column punched card. It is used for personnel, financial, and stock accounting. The card is divided into vertical and horizontal columns. On this card the numbers 1 through 80 appear horizontally at the top of the card and are printed again horizontally at the very bottom of the card.



80-Column Card

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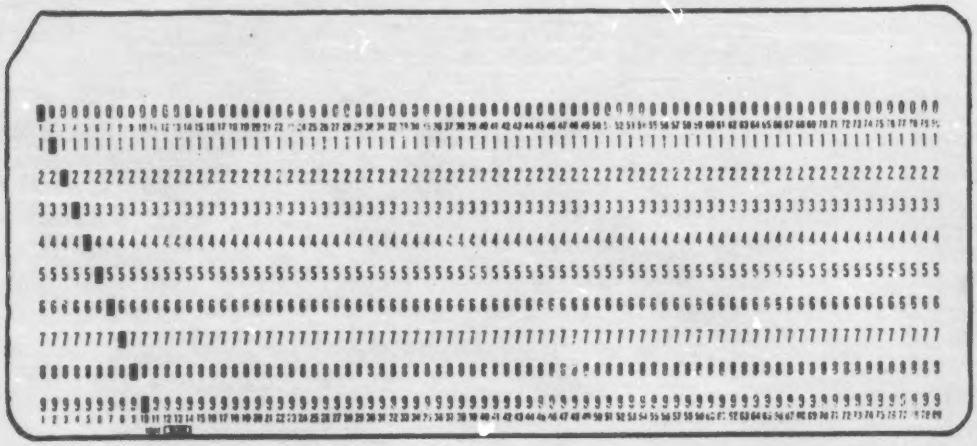
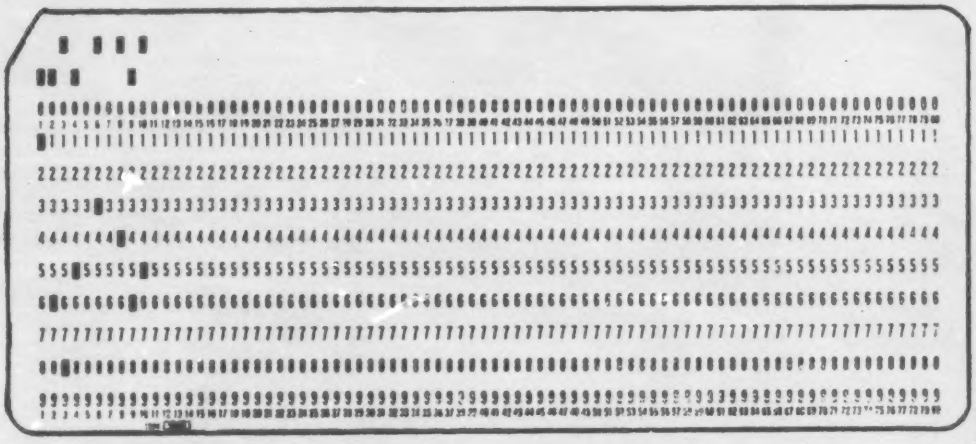
Each column contains the numbers 0 through 9, running vertically. To record any number, we would punch the position that represents that number. On the upper left portion of the card, you will notice the numbers 0 through 9. The card has been punched to correspond with the printed order. You will notice a 0 under column 1, 1 under 2, all the way through 9.



In using columns, we need one column for each digit or character punched. Examine the card below. The name JOHN C DOE has been punched. Columns 1 through 4 are used to record "JOHN"; column 5 is blank to denote a space; column 6 records the middle initial "C"; column 7 is a blank space; and columns 8, 9, and 10 are used to record "DOE."



How many columns would you use to punch the name CHARLES W JOHNSON?

_____

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17

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
C H A R L E S   W     J O H N S O N
```

---

2. Columns on a punched card are combined to form fields. Fields are one column or a group of consecutive columns of a punched card that are set aside for a specific item of information. In the example below we have three fields: name field, social security number (SSN) field, and grade field.

```
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
J O H N   C   D O E      3  0  9  3  2  1  7  2  3     S  S  G

  NAME FIELD                    SSN FIELD                GRADE FIELD
```

We can see that columns 1 through 10 represent the name field; column 11 is a space; columns 12 through 20 represent the SSN field; column 21 is a space; and columns 22 through 24 represent the grade field.

Using the information below, list the appropriate column numbers for the name field, SSN field, and grade field. Also indicate which numbered columns would be space columns. Use the space provided.

JACK T JONES 309 33 3987 SSG

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1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
J	A	C	K		T		J	O	H	E	S		3	0	9	3	3	3	9	8	7		S	S	G

Name field: Columns 1 through 12
SSN field: Columns 14 through 22
Grade field: Columns 24 through 26
Spaces: Columns 5, 7, 13, and 23.

---

3. As a review of previous instruction, answer the following questions:

a. How many columns are there in the punched cards used most frequently by the Army? _____

b. What name is given to a column or a group of consecutive columns on a punched card that are set aside for a specific item of information? _____

c. How many columns would normally be used to punch the name of JOE SMITH?

_____

72

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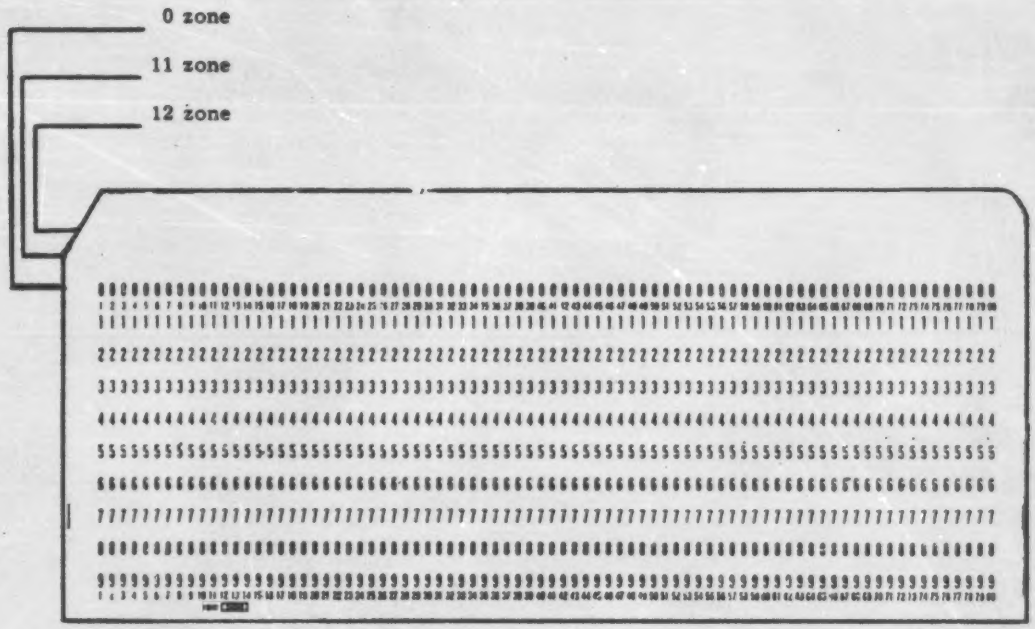
a. 80
b. Field
c. Nine.

---

4. A card has three zone punches, as shown below. These zones are named the "12-zone punch," the "11-zone punch," and the "0-zone punch."



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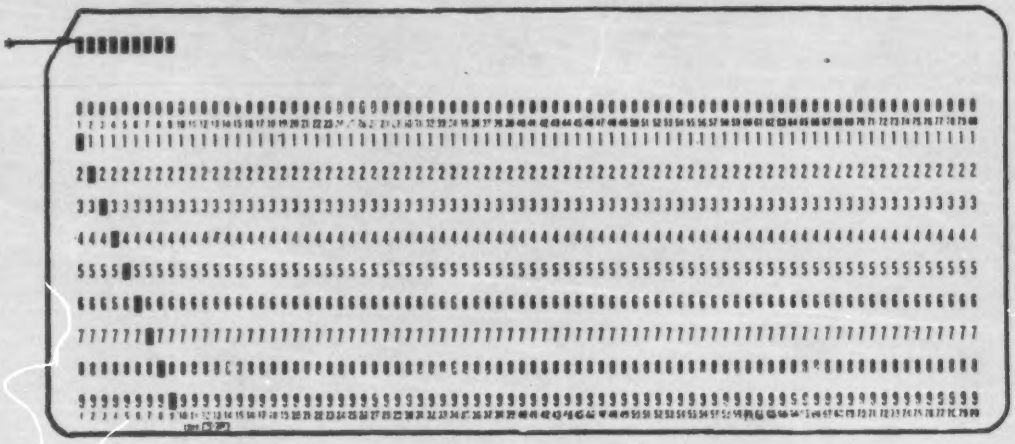
a. We shall discuss the 12-zone punch first.



Refer to the card above. You will notice an asterisk marking a row of nine punches in the upper left corner of the card. These punches are 12-zone punches. The 12-zone punch is used in combination with a numeric punch to form alphabetic characters A through I. To punch an A on the card, you would punch the 12 zone and 1; for a B, you would punch the 12 zone and 2. This process continues all the way through the letter I, which is represented by a 12-zone punch and a 9.

Using the above information, complete the following:

(1) a 12-zone punch and a 3 punch = _____.

(2) a 12-zone punch and a 5 punch = _____.

(3) a 12-zone punch and an 8 punch = _____.

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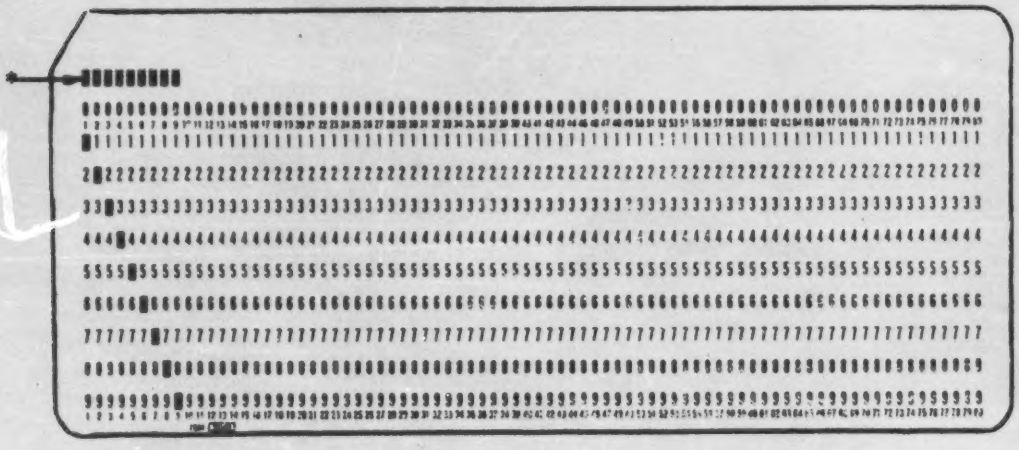
(1) C
(2) E
(3) H

---

b. Next we shall consider the 11-zone punch.



Refer to the card shown above. The asterisk marks a row of punches in the 11 zone. The 11-zone punch is used in combination with a numeric punch to form alphabetic characters J through R. To punch a J, you would punch the 11 zone and 1; for the character N you would punch the 11 zone and 5. This continues in order all the way through R. An 11-zone punch and a 9 represent an R.

Complete the following:

(1) A 12-zone punch and a 4 punch = _____.

(2) An 11-zone punch and a 3 punch = _____.

(3) An 11-zone punch and a 7 punch = _____.

(4) A 12-zone punch and a 6 punch = _____.

(5) An 11-zone punch and a 5 punch = _____.

(6) A 12-zone punch and a 9 punch = _____.

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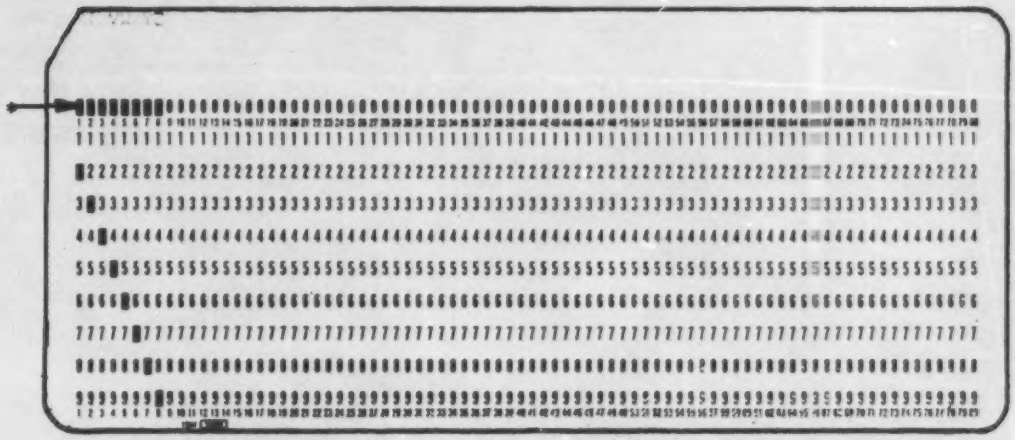
(1) D
(2) L
(3) P
(4) F
(5) N
(6) 1

---

c. Now let's look at the 0-zone punch.



Refer to the card shown above. The asterisk marks the 0-zone punches that, combined with a numerical punch, represent the remainder of the alphabet. With our 12- and 11-zone punches we used nine numeric characters each. There are 26 letters in the alphabet; therefore, we have only eight letters to be formed with the 0-zone punch, S through Z. Since there are only eight letters, we start with a 0-zone punch and a 2 punch to form an S; T is represented by a 0-zone punch and a 3 punch; and Z is formed by a 0-zone punch and a 9 punch.

Complete the following:

(1) A 12-zone punch and a 2 punch = _____.
(2) An 11-zone punch and a 2 punch = _____.
(3) A 0-zone punch and a 2 punch = _____.
(4) A 0-zone punch and a 6 punch = _____.
(5) An 11-zone punch and a 5 punch = _____.
(6) A 12-zone punch and a 4 punch = _____.
(7) A 0-zone punch and a 7 punch = _____.
(8) An 11-zone punch and an 8 punch = _____.
(9) A 12-zone punch and a 9 punch = _____.

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(1) B
(2) K
(3) S
(4) W
(5) N
(6) D
(7) X
(8) Q
(9) I

---

5. Following is a summary of the punches required on an 80-column card to represent alphabetic characters:

12-ZONE PUNCH	11-ZONE PUNCH	0-ZONE PUNCH
and 1 = A	and 1 = J	and 2 = S
and 2 = B	and 2 = K	and 3 = T
and 3 = C	and 3 = L	and 4 = U
and 4 = D	and 4 = M	and 5 = V
and 5 = E	and 5 = N	and 6 = W
and 6 = F	and 6 = O	and 7 = X
and 7 = G	and 7 = P	and 8 = Y
and 8 = H	and 8 = Q	and 9 = Z
and 9 = I	and 9 = R	

Write the name "JAMES C WILSON," using the code shown above.

a. 11 and 1 = J

b. __ and __ = A

c. __ and __ = M

d. __ and __ = E

e. __ and __ = S

f. __ and __ = C

g. __ and __ = W

h. __ and __ = I

i. __ and __ = L

j. __ and __ = S

k. __ and __ = O

l. __ and __ = N

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a. 11 and 1 = J

b. 12 and 1 = A

c. 11 and 4 = M

d. 12 and 5 = E

e. 0 and 3 = S

f. 12 and 3 = C

g. 0 and 6 = W

h. 12 and 9 = I

i. 11 and 3 = L

j. 0 and 2 = S

k. 11 and 6 = O

l. 11 and 5 = N

ARMY--APG, MD--567-W

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SUPPLEMENTAL PAMPHLET

905-2

INTRODUCTION TO AUTOMATIC DIGITAL COMPUTERS

OCTOBER 1973

DEPARTMENT OF ARMY WIDE TRAINING SUPPORT
US ARMY ORDNANCE CENTER AND SCHOOL
ABERDEEN PROVING GROUND
MARYLAND

4-1

SUPPLEMENTAL PAMPHLET 905-2

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SECTION I. INTRODUCTION

1. GENERAL.

a. The first look at the equipment (hardware) that makes up an automatic data processing system (ADPS) is awe inspiring. The size of an ADPS is in no way comparable to a comptometer, punched card machine, or any other calculating device. It actually fills a large room (fig 1). Spools of tape spin erratically within rows of cabinets, lights flash and blink off and on, and printed copy spews forth as evidence of work performed.

b. In the early days of automatic data processing, computers were considered to be gigantic "brains" or electronic "monsters." Even today, the special language of the people involved in processing data through ADPS could easily evoke visions of their being recruited from another planet.

c. Automatic data processing systems are not mysterious and they certainly are not brains because they cannot think—even in the most elementary way. They are capable of doing only what some human being tells them to do. The most inept clerk in your organization is a regular "Einstein" compared to this roomful of electronic computing equipment. However, the computer is fast and accurate. This is the reason the Army uses ADPS. One of the most significant factors in modern warfare is time. We must be able to move large numbers of men and their records great distances on short notice. Coupled with this requirement is the steadily increasing need to reduce man-hours for the sake of economy. An effective method to meet these needs is the increased use of ADPS.

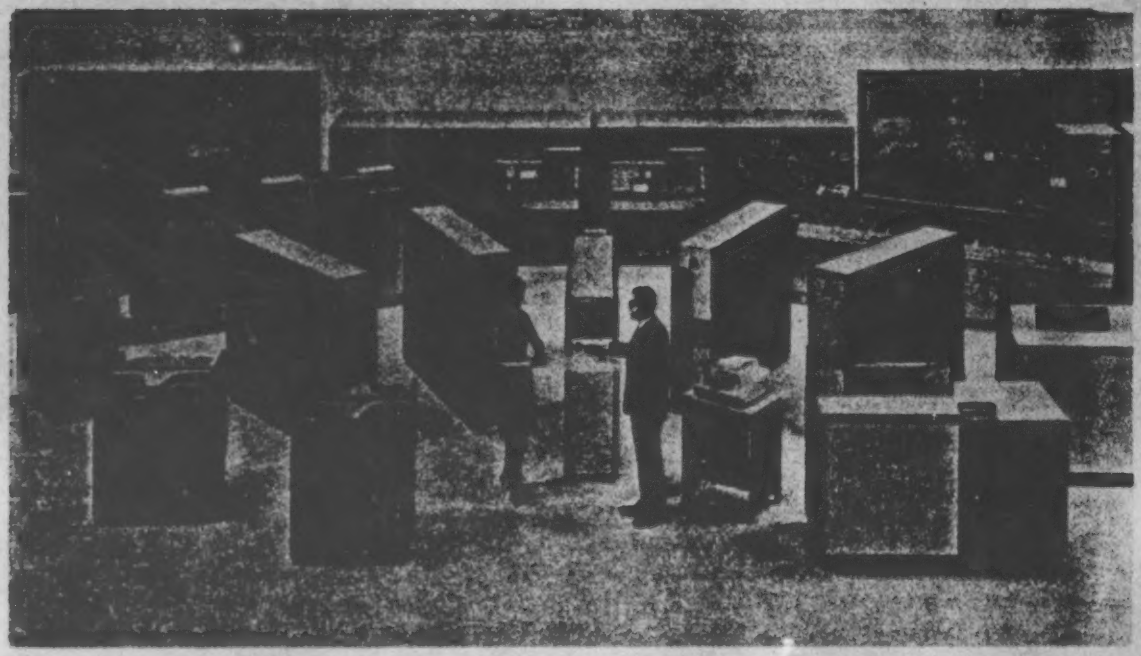

Figure 1. Modern large-scale computing system (Burroughs B3500).

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2. EXPLANATION OF THE TERM "ADPS." Data processing may be defined as preparing source documents, which contain basic elements of information or data, and handling this data (sorting, calculating, summarizing, and recording) to produce records and reports. We take data from source documents and compile it in records for future use in reports. However, while keeping in mind our overall job, we should also minimize the number of source documents, eliminate unnecessary and out-dated records, and speed up the production of reports.

a. A tremendous aid in the field of data processing came into practical use during World War II in the form of the punched card system. Punched cards brought to the data processing field speeds and flexibility that were unknown before. Today, they are widely used and almost universally accepted as an excellent means of data processing. They are by no means finished; punched cards will be with us for many years to come.

b. However, even with the speed attained with punched card equipment, we still could not keep pace with the increasing demands for data. Punched card equipment is electromechanical in nature; therefore, the speed of processing is limited by the rate of movement of mechanical parts. Further, inasmuch as punched card equipment consists of several types of machines, each with a specialized ability, the chain of processing is not continuous. The cards must be transferred between machines by a human being to accomplish the required operations. These shortcomings led to the development of ADPS.

c. Webster's New World Dictionary defines the word "data" as "things known or assumed; facts or figures from which conclusions can be inferred." From this we can interpret "data processing" as the manipulation of these facts or particles of information. By "data processing system" we mean the interacting assembly of personnel, procedures, and equipment to perform data processing operations. Actually, we have had many machines and methods in the past that have been described by all three of these words, but it is the addition of the fourth word, "automatic," that makes the difference. Here is where the new concept enters the picture. "Automatic" means that the work is done with a minimum of human intervention, and the manipulation of the information takes place within a complete, closed unit. It is no longer necessary to carry cards from place to place, entering and re-entering data into machines. The machine not only furnishes its own operating energy but it also furnishes its own control, once we have told it what to do. Our explanation is now complete: an automatic data processing system is an interacting assembly of personnel, procedures, and equipment to perform data processing operations within a closed, complete unit with a minimum of human intervention.

d. A total ADPS is an interacting assembly of personnel, procedures, and equipment. The terms used in describing these physical elements of an ADPS are listed below.

(1) Hardware—the physical equipment or devices forming a computer and its peripheral equipment.

(2) Software—the programs and procedures (e.g., SOP, operator's manuals, and programers' manuals).

(3) Personnel—the ADPS managers, analysts, programers, operators, and maintenance technicians.

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3. ADVANTAGES OF A COMPUTER. The need for some means of automatically computing data led to the development of new hardware in the form of the electronic digital computer. This equipment allows us to use the word "automatic" in our explanation. The computer has the following specific advantages:

a. Speed. Without a doubt the major advantage of a computer over punched cards and other systems is speed. An example of this speed is the time required to add two simple, five-digit numbers, such as 14,712 and 17,171, which equal 31,883. This is a simple problem; however, if we had 10,000 of these problems, we would need about 4 working days to add them on an adding machine. An electronic computer can solve 10,000 problems of this type in one-tenth of a second. With this capability we can update every file every day if we want to, because actual calculations take very little time.

b. Accuracy. A computer seldom makes a mistake on its own. Of course, if we put incorrect data into a computer, we will get incorrect information out of it. But the computer is almost infallible. If it does make an error, it signals the operator that it has erred.

c. Ability to execute preplanned operations. The stored program, or set of instructions, gives the computer all its instructions. The program is the preplanned operation. No similar preplanning was possible with former data processing equipment.

d. Ability to perform new tasks.

(1) With the three capabilities just mentioned, we can perform tasks that were never feasible before. For example, for many years the mathematical and statistical techniques that are now available to management were not possible because of the time required to calculate and because of the many chances for human error. These techniques are now applied widely in business, industry, and the military services because the computer is available as a sophisticated tool of management. Many facets of our life today would be impossible without computers. For example, due to the mass of data now involved, even such a seemingly routine task as operating the Federal Reserve banking system for processing personal checks could not be done without computers.

(2) Most of us know vaguely that computers have something to do with space flights such as the Apollo moon missions. However, the extent to which the success of such ventures depends on computers is not apparent to the casual observer. For example, most Americans are familiar with the scenes on television showing a large room in Houston in which the controllers for the flights sit in front of what appear to be individual television sets. These "television sets" are actually output devices (video displays) for computers. The individuals who study the output of these devices are specialists, and specific types of information are displayed on separate terminals (e.g., medical information on one device). The multitude of computers that process and display data are not seen in the television coverage.

(3) The entire space program is an excellent example of a situation requiring the advantages of a computer. The sheer volume of data and the involved calculations that must be performed in seconds (such as the exact length of time that a retrorocket should fire) would make it impossible to have the data processed by humans. The computer's accuracy is also essential since even a small error could not be tolerated.

e. Capacity for making decisions. The computer can actually make decisions, although these decisions are of a limited nature and must be outlined in advance by programming.

f. Ability to transmit decisions. Through electronic data transmission devices that are tied into our ADPS, we have the ability to send our decisions to predetermined locations. The Army's long-range plan is to have all military computers tied in to each other by direct communications means so that computers can "talk" to each other without human intervention.

4. CLASSIFICATION BY USE. In classifying computers (fig 2) we should ask three questions: How does it internally represent data? For what purpose was it manufactured? What is its size and cost?

CLASSIFYING COMPUTERS

HOW DOES IT INTERNALLY REPRESENT DATA?

Digital? ----- Analog?

FOR WHAT PURPOSE WAS IT MANUFACTURED?

Special? ----- General?

WHAT IS ITS SIZE AND COST?

Small? ----- Medium? ----- Large?

Figure 2.

a. Data representation. First, we must inquire into the way in which a computer internally stores or represents data. Data can be represented in one of two ways: analog or digital.

(1) Analog computer. An analog computer continuously records data by a graph or dial. It makes a continuous representation of changing conditions. This computer uses quantities of physical variables (such as position, shaft rotation, voltage, or measurements of physical quantities) for calculations by simulating the problem in terms of physical relationship. The computer is operated by inserting the information into the device manually or by permitting other sources to feed information automatically. The output can be used directly or transformed into some automatic control action. In simple terms, we can say that analog computers measure and digital computers count. Two examples of an analog computer are given below.

(a) In the thermometer, the physical expansion or contraction of mercury is read on a graduated scale as a temperature.

(b) The speedometer of a vehicle is coupled by gears and a flexible shaft to the vehicle's drive shaft. The speed of the vehicle is indicated by the pointer of the speedometer. The rotation of the drive shaft is a physical quantity represented by the speedometer pointer.

(2) Digital computer. This computer makes a discontinuous representation of a fixed condition. It uses representations of data in a numerical form for input and output information. Numbers or digits are used in arithmetic operations of addition, subtraction, multiplication, and division within the machine. The digits or numbers can be fed into the computer by a keyboard much like that of a typewriter. Machine registers store information and perform the required operations in separate steps. Digital counting can be of several types, such as counting holes in a paper card or tape, the teeth on a gear wheel, or electrical pulses in a circuit. Two examples of simple digital computers are given below.

(a) Mileage counter. The mileage counter (fig 3) on a vehicle odometer consists of six dials rotated by a flexible shaft connected to the vehicle's drive shaft. This counter gives the driver a visual indication of the distance traveled. When the tenths-of-a-mile dial completes a full rotation as it moves from 0 through 9 and back to 0, the 1-to-9-mile dial moves from 0 to 1. In effect, this dial counts or adds the number of turns completed by the tenths-of-a-mile dial. This same operation continues from the 1-to 9-mile counter to the tens-of-miles counter. Similar indications are found on the other dials. Because each dial computes the distance traveled and indicates precisely one digit, the mileage indicator is a form of a digital computer.

(b) Pinball machine. This machine also uses the digital computer process. To win a certain number of free games, the player must score a set number of points or light certain lamps. The machine requires certain contacts to be closed by hitting a peg with a ball for some part of the required score. If the player is lucky, the required number of contacts are closed, the digital process is completed, and a number of free games are available.

(3) Hybrid computer. When digital and analog data representations are combined, a hybrid computer is produced. Since it is a combination of the two major types of computers, the hybrid computer is not considered a major computer category in itself. Hybrid representation is used for control purposes in the petroleum industry. For example, oil flowing through a pipe is measured by means of analog data representation and then converted to digital data to be used in computations to control various processing functions within the refinery complex.

b. Purpose. Next we must ask whether the computer is designed for a special purpose or whether it is a general purpose computer.

(1) Special purpose computer. This type of computer is able to solve only one type of problem and, in this respect, is similar to many analog computers. The program for this problem is built into the computer so that, whenever the data words are supplied, a solution is produced. A variation of the special purpose computer is the plugboard or patch panel computer. In this computer, the program is wired in on an externally available or interchangeable plugboard. This type of computer can be made smaller and lighter, thus requiring less power than a general purpose computer because of the reduction in size of memory and control circuits. Although special purpose computers are not as common as general purpose computers, they may well be used where a particular problem is to be solved, such as in a control system in which size and weight are critical factors.

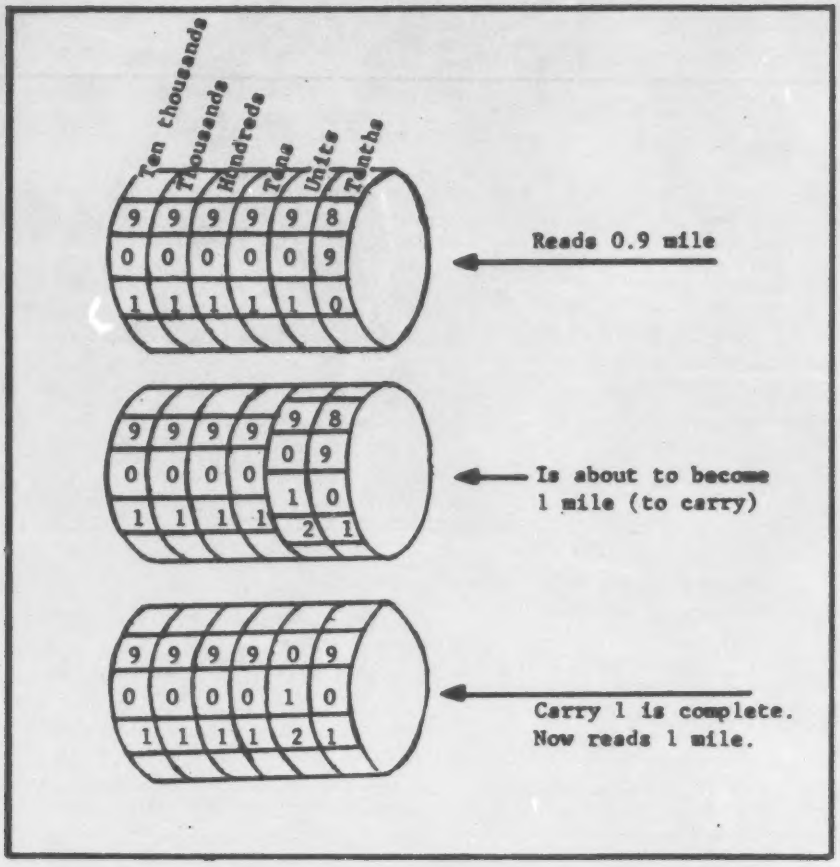

Figure 3. Mileage counter.

(2) General purpose computer. This type of computer is capable of solving a wide variety of problems in the areas for which it was designed. The distinguishing characteristic of a general purpose computer is that it is incapable of solving any problem until the method of solution is correctly programed and stored in the computer. The computer is used for either scientific or business purposes. Business applications are characterized by a large amount of input, a small amount of computation, and a large amount of output. Scientific applications usually consist of a small amount of input, a large amount of computation, and a small amount of output. Any computer can do either of these two applications, but some computers are more suited to one application than another.

c. Size and cost. Finally we can ask about the size and cost of a computer. There are three classes into which we can categorize these computers: small scale, medium scale, and large scale. This area will be discussed in more detail in section IV of this pamphlet.

SECTION III. COMPUTER ARITHMETIC

5. GENERAL. Someone has said that the greatest task before civilization today is to make machines what they ought to be—the slaves, instead of the masters, of men. This is a salient point to consider in the use of computers. Actually, the computer is just a useless metallic monster which occupies valuable office space unless we are able to control it through various means of communication.

6. OBJECTIVES. Before conversing with people who speak only a foreign language, it is necessary to learn their language. Similarly, when operating a machine that understands only a specific language, it is necessary to know and be able to use that language. Unlike the foreigner who may be able to help us with our communication problems, the machine is an inanimate object. Our problem is greater since we must completely master the machine's language. In this instruction we will consider the various ways in which data is represented within a computer, how information is remembered, and how arithmetic functions are performed.

7. COMPARISON OF BINARY AND DECIMAL NUMBERING SYSTEMS. Traditionally, the decimal numbering system, with which we are all familiar, is used for arithmetic procedures; but this system is not suited to the operation of electronic computers. The decimal system uses 10 distinct digits—0, 1, 2, 3, 4, 5, 6, 7, 8, and 9; we use this system because we have 10 fingers. Electronic computers are made up of switching devices, such as transistors and magnetic elements, that have only two definite states. They are either ON or OFF—positive or negative. Therefore, the computers use the binary numbering system because their components have only two possible positions—ON and OFF. The binary, or "two-finger," arithmetic is the heart of electronic computer design. It is through the binary system that we are able to use the high speed of modern electronic calculating machines.

a. <u>The need for a binary numbering system.</u> The requirement of the binary numbering system is imposed by the nature of the electronic equipment now available. Since the circuits and physical characteristics suitable for use in a digital system have only two distinct states, it is only logical to organize such circuits into an arrangement for performing binary manipulation. For example, we can have the OFF condition represent the digit 0 (zero) and the ON position represent the digit 1. But how do we represent the digits 2 through 9? We have no way of using the decimal system directly. Therefore, in computers, we use the binary numbering system with which we can represent any number by using only the digits 0 and 1.

b. <u>Decimal numbering system.</u> Let us examine the decimal numbering system more carefully in order to be able to compare it more minutely with the binary system, which is truly the language of the computer. As we have said, the decimal system uses 10 distinct symbols—0 through 9. With these symbols we can represent any value from 0 through 9 in a single digit position, the units position (10^0). (In a decimal number digits have individual values of 0 through 9 and position values that are multiples of 10, the number base of the decimal system. The first digit to the left of the decimal point is multiplied by 10^0, which is equal to 1, so that the first digit is counted at face value. The second or tens digit is multiplied by 10^1, which is 10. The hundreds digit is multiplied by 10^2, which is 100, and so on.)

Units
10^0
9

(1) However, beyond 9 our decimal system has to resort to a trick of the mathematical trade and use two symbols or digits. Consequently, in order to symbolize 10, we simply carry a 1 into a second digital position, the 10's position (10^1). Now, by using all the digit symbols in both the units and 10's position, we can represent any value from 0 through 99.

Tens	Units
10^1	10^0
9	9

(2) Here we hit our second snag. To continue, we must slip in another position, the 100's position (10^2). Similarly, by increasing to more and more digit positions (1,000's, 10,000's, and so on) we can represent any number with the decimal system.

Tens of Thousands	Thousands	Hundreds	Tens	Units
10^4	10^3	10^2	10^1	10^0

(3) With each new digit position that we add we increase the value of our number symbols 10 times. For example, a 7 in the 10's position (10^1) is worth 10 times the amount in the units position (10^0); in the 100's position (10^2) the 7 is worth 10 times the amount in the 10's position (10^1) and so on.

8. HOW THE BINARY NUMBERING SYSTEM WORKS. The binary system works on the same principle except that we have only two different symbols with which to work, the 0 and the 1. To write the value of 0, we simply write a 0; and to indicate the value of 1, we write a 1. Beyond this it is necessary to resort to the same type of trick that we used in the decimal numbering system.

a. The 2's position (2^1). Although in the decimal system we did not have to carry a number to the next position until we reached 9, we are already forced to carry in the binary system. In the binary system our next digit position (corresponding to the 10's position in decimal arithmetic) is the 2's position (2^1). A 2 then is very simply represented by a 1 in the 2's position and a 0 in the units position. A 3 is recorded by the digit 1 in the 2's position and also in the units position.

b. The 4's position (2^2). Again, we have run out of digits, and in order to represent the value of 4 we must establish a new digit position. Therefore, the 4's position is established in the same place that the 100's position appears in the decimal system. A 4 is simply recorded by placing a 1 in the 4's position, with 0 in both the 2's and units positions. A 5 is recorded by a 1 in the 4's position, a 0 in the 2's position, and a 1 in the units position; a 6 is represented by a 1 in the 4's position, a 1 in the 2's position, and a 0 in the units position; and a 7 is made by a 1 in each of the 4's, 2's, and units positions.

c. The 8's position (2^3). Again, with our position full of 1's, we must create another position, the 8's position. To record 8 we simply have a 1 and three 0's (1000); and 9 is recorded by a 1, two 0's, and another 1 in the units position (1001). (Notice that in the decimal system each new digit position has 10 times the value of the preceding one, but in the binary system each new digit position has 2 times the value of the preceding one.) Figures 4 and 5 more graphically present the binary numbering system.

Decimal Numbers	Binary Numbers
0	0000
1	0001
2	0010
3	0011
4	0100
5	0101
6	0110
7	0111
8	1000
9	1001

Figure 4.

In straight binary arithmetic, the number "53" is recorded as follows:

2^5	2^4	2^3	2^2	2^1	2^0
32's	16's	8's	4's	2's	1's
1	1	0	1	0	1

The decimal equivalent of the binary number shown in the above illustration is determined as follows:

1 in the 1's position = 1
0 in the 2's position = 0
1 in the 4's position = 4
0 in the 8's position = 0
1 in the 16's position = 16
1 in the 32's position = 32
110101 = 53

Figure 5.

d. The binary number 110101 represents 53 in the decimal system. You can readily see that this number (110101) could be represented very easily by six electronic switches where OFF has a value of 0 and ON has a value of 1. If you do not understand the binary system from the information presented here, study appendix II. It presents another explanation of this system.

9. PRACTICAL EXERCISE NUMBER 1. To be sure that you understand the binary numbering system, convert the following decimal numbers into straight binary numbers. The answer to this practical exercise is found in appendix III.

	32	16	8	4	2	1
6 =						
7 =						
9 =						
10 =						
11 =						
20 =						
23 =						
32 =						
40 =						
45 =						
50 =						

10. TRANSLATING DECIMAL NUMBERS INTO BINARY NUMBERS. One way to translate a decimal number into a binary number is simply to divide the number by 2 and record all remainders until we reduce the number to 0. For example, to determine the binary symbol for 23 (fig 6) we divide by 2 as follows: 23 divided by 2 equals 11 with a remainder of 1. This 1 is recorded and we divide the 11 by 2 again. This answer is 5 with a remainder of 1. We then place this 1 in front of the first 1 and divide the 5 by 2. This answer is 2 with a 1 remainder. This 1 is again placed in front of the other two 1's. Then we divide the 2 by 2, getting an answer of 1 with no (or 0) remainder. This 0 is now placed in front of the three 1's (0111). Finally, we divide 1 by 2 and get 0 with a 1 remainder. By placing this final 1 beside the 0 and the three 1's (10111), we get the binary number of 23. It is important to note that we record the 0 remainders as well as the 1's.

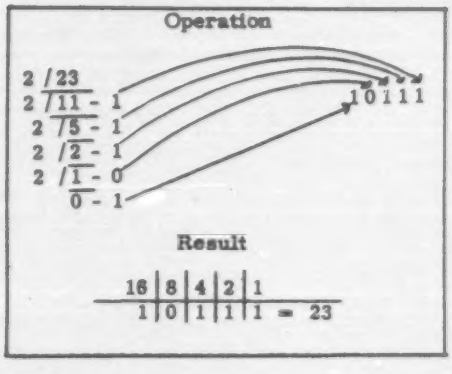

Figure 6.

11. PRACTICAL EXERCISE NUMBER 2. If you understand how decimal numbers are converted to straight binary numbers, you should be able to translate the following numbers into straight binary numbers. Test yourself. The solution to this practical exercise is found in appendix III.

	1024	512	256	128	64	32	16	8	4	2	1
25 =											
50 =											
100 =											
500 =											
1,200 =											
1,967 =											

12. ARITHMETIC OPERATIONS. The arithmetic operations performed in most computers are the obvious ones of adding, subtracting, multiplying, and dividing. The ability of the computers to do this is not unusual; what is significant is the electronic speed with which they perform these operations. These machines are so fast that minutes and seconds are far too long for conveniently measuring their speed. The usual units of time are the milli-second (one-thousandth of a second), the microsecond (one-millionth of a second), the nanosecond (one-billionth of a second), and the picosecond (one-trillionth of a second). Many of these computers can add or subtract at the rate of 16,600 computations a second. The automatic computer can add, complement, and shift. Through these basic abilities, it can perform all the operations in fundamental arithmetic.

a. Binary addition. Binary addition is performed in practically the same manner as decimal addition; one binary number is placed below another and they are added. Whereas in decimal addition we carry a number from one column to the next if the total of the first column exceeds 9, in binary addition we must carry a number to the next column if the number in the first column exceeds 1. See figure 7 for examples of binary addition.

Decimal	Binary	Decimal	Binary
4	0100	5	0101
+2	+0010	+1	+0001
6	0110	6	0110

Figure 7.

b. Binary subtraction. Computer subtraction is done by complementing. In manual complementing, the complement of a number is the amount that must be added to that number to make a total of 9. The complement of the subtrahend (the amount we want to subtract) is added to the minuend (the larger number, or the number from which we are subtracting). Upon completion of this addition, the 1 appearing as the first digit of the answer is removed and added to the last digit of the answer. The same procedure occurs in binary complementing, except that the complement is that number which must be added to the subtrahend to make a total of 1111. Figure 8 describes one method of subtracting. There are other methods of accomplishing this process.

Human Method	Manual Complementing	Computer Method
8	8 (complement)	1000
-2	+ 7 ← (of 2) →	+ 1101
6	15	10101
	+ 1	+ 1
	6	0110

NOTE: In this example, the 7 is the 9's complement of 2 and the 1101 is the 1's (1111) complement of 0010 (2).

Figure 8.

c. Binary multiplication. Multiplication in the binary system is performed in the same manner as in the decimal numbering system. The examples shown in figure 9 illustrate this procedure quite clearly.

Decimal System	Binary Method	Decimal System	Binary Method
4	0100	3	0011
x3	x0011	x5	x0101
12	0100	15	0011
	0100		0011
	01100 = 12		001111 = 15

Figure 9.

d. Binary division. Binary division is performed by a process of repeated subtraction. The divisor (the number by which another is divided) is subtracted from the dividend (the number that is to be divided) until the dividend is reduced to 0. The number of subtractions required are counted, and this counted number is the quotient (answer). When there is no binary carry out, the computer considers the result to be negative and recomplements to 0. Figure 10 illustrates this procedure more clearly.

Human Method	Manual Subtraction	Binary Subtraction*
$2\overline{)8}\ \ 4$	8	1000 .
	$\frac{-2}{6}$ - 1	+ 1101
		0101
		→ 1 1
	$\frac{-2}{4}$ - 2	0110
		+ 1101
	$\frac{-2}{2}$ - 3	0011
		→ 1 2
	$\frac{-2}{0}$ - 4	0100
		+ 1101
		0001
		→ 1 3
		0010
		+ 1101
		1111
		0000 4

*When there is no carry out, the computer recomplements to 0.

Figure 10.

13. BINARY-CODED DECIMAL SYSTEM. Thus far, we have discussed the coding system which is called straight binary representation. This type of coding system is used in the computers designed for scientific calculations. Thirty magnetic cores or binary digits (bits) can represent quantities up to 10 billion. This manner of representation facilitates arithmetic computations, but it is not suited for data processing. In data processing systems we want to be able to recognize every digit of a code; consequently, we cannot translate a large number into one large binary translation. Instead, we must use the binary-coded decimal (BCD), which translates every digit separately. For example, the decimal number 345 would be represented in a straight binary representation as follows: 101011001. However, to use this figure to best advantage in a computer, we must separate 345 into three digits: the 3 (represented by 0011 in binary arithmetic), the 4 (0100), and the 5 (0101). Four binary digits are required in binary-coded decimal to represent one decimal digit. Therefore, eight binary digits would be required to represent two decimal digits, 12 binary digits would be needed for three decimal digits, and so on. The binary-coded decimal symbol for each number from 0 to 9 is written in the same manner as it is in straight binary. Some computer systems use 1010 to represent 0; however, many authorities use 0000 as the binary-coded 0 decimal. Other examples which provide a clearer picture of binary-coded decimal are shown in figure 11. It is interesting to note at this time that the translations from decimal to binary representation are done by the computer automatically.

Decimal	Binary (Decimal Coded)			
27			0010	0111
96			1001	0110
813		1000	0001	0011
4,075	0100	0000	0111	0101

Figure 11.

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14. PRACTICAL EXERCISE NUMBER 3. You should be able to translate the following numbers into binary-coded decimal. Test yourself. The solution to this practical exercise is found in appendix III.

		8421	8421	8421	8421
33	=			0011	0011
76	=				
100	=				
295	=				
471	=				
1,560	=				
1,967	=				

SECTION IV. FUNCTIONAL ELEMENTS OF A COMPUTER

15. BASIC FUNCTIONAL COMPUTER ELEMENTS.

a. According to the Dictionary of United States Army Terms, a system is "an integrated relationship of components alined to establish functional continuity toward the successful performance of a defined task or tasks." Webster's New World Dictionary defines it as a "regular, orderly way of doing something." Regardless of the definition, a system is designed for a specific purpose—to accomplish a particular task in a minimum amount of time. Automatic data processing systems are no exception.

b. A system establishes an orderly way of doing something, but this does not mean that the system will be simple in its operation. Many complex systems are in operation today. Automatic data processing systems usually fall into the complex category because they involve the interaction of personnel, procedures, programs, and ADP equipment to perform a complex of data processing operations. There are many types of data processing systems, all of which vary in size, complexity, speed, cost, and application. However, all data processing involves at least three basic considerations.

(1) The source data or input entering the system.

(2) The orderly, planned processing within the system.

(3) The end result or output from the system.

16. PHYSICAL COMPONENTS.

a. Communication. The physical components (fig 12) of an ADPS, such as communication, input, output, control, arithmetic and logic unit, and storage, are discussed in the following paragraphs. Communication devices including data transmission devices are not considered as components of an ADPS unless they operate online. To be considered "online," the device must operate under control of the central processing unit. A remote inquiry unit would be an example of a data transmission device which would be a component of the system. Usually, such devices are considered as input-output units rather than data transmission devices. This is true even if the data is transmitted over great distances. Communication devices especially those within the category of data transmission devices are used to move to the data processing center and away from it. Since most operate offline, they are not considered as components of an ADPS.

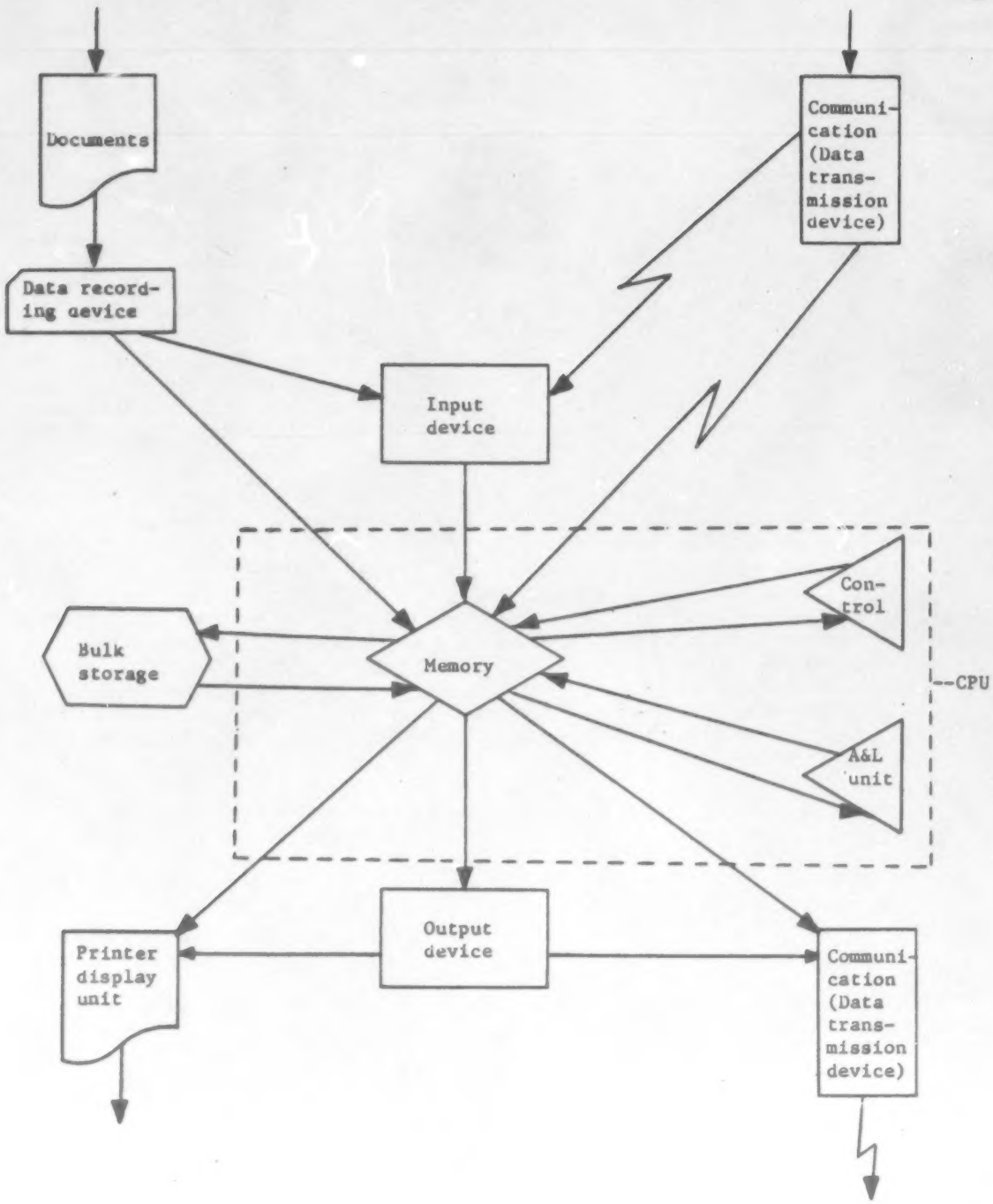

Figure 12. Components in the ADP system.

b. Input. Input is the element responsible for getting both instructions and data into the computer. Because a computer is incapable of education, it is unable to understand the printed word. For this reason we must convert human language into some form of language intelligible to a machine through circuitry design. We can do this with punched cards, magnetic tape, or paper tape. Punched cards are an inexpensive medium, are easy to sort, and, despite their relative slowness, are a primary source of input. Magnetic tape is extremely fast, has a large capacity, is easy to store, and is reusable. This type is increasing in popularity as a means of input. Paper tape is also inexpensive, is easy to store, and has a fairly large capacity, but it is seldom used as a primary medium of input.

c. Output. Output is very similar to input—working, of course, in the opposite direction and furnishing our finished product. Output from a computer may be defined as modified or updated input information. Output may be in either readable or nonreadable form. Information that is in finished and readable form appears as a printed page or hard copy. Nonreadable output may take many forms. The most frequently used types are magnetic tape and punched cards. Punched paper tape is also available as an output medium in certain systems. (Punched cards and punched paper tape can be manually read. However, this is difficult and time consuming. Because of this difficulty and the fact that the data encoded in such media are not printed characters, they are considered as nonreadable input and output.)

d. Control. The control element is responsible for directing the computer in performing its operations. Control gets its orders from the program, which a human user has prepared. Control is the element that carries out the program steps in their proper sequence.

e. Arithmetic and logic. Another element closely associated with storage is the arithmetic and logic unit. This is the unit that does all the mathematical work in the computer. A computer can add, subtract, multiply, divide, and test. It is the test operation that makes a computer so useful. In testing, a computer can answer "yes" or "no" to one of three questions: Is the number we're concerned with positive? Is it negative? Is it zero? Any complex action or activity can be broken down into a series of these simple decisions.

f. Storage. The storage element of a computer holds information needed to perform the necessary computations. (The storage element is sometimes referred to as memory.) It holds both the data to be worked upon and the instructions for processing it. In storage we also have a place to hold the intermediate results of calculations. For these and other reasons we must have various devices for storing information. A magnetic drum is one storage device; it spins on its axis and allows data to be recorded on its surface. A magnetic core is another storage device. It is made up of iron, doughnut-shaped rings, each of which is placed at the intersection of two wires. The way each ring is magnetized (polarity) indicates the number stored there. It has very fast access time but is very costly. Another storage device is the magnetic disk, which is something like a phonograph record except that it is larger. It has no grooves on its surface, but the elements of data are stored in the form of magnetized spots. This process is fairly slow, but it can handle a great amount of information. The IBM RAMAC system uses this type of storage. One of the latest developments in the field of computer storage is thin film, which is a thin piece of glass containing magnetized spots. It provides the fastest type of memory, but its use is limited because of its high cost.

SECTION V. CLASSIFICATION OF COMPUTERS BY GENERATION

17. HISTORICAL EVOLUTION. The history of digital counting, calculating, and computing devices dates back thousands of years when beads were strung on a reed or other string-like object. Although very simple to use, these stringed beads constituted a major advance in the mechanization of counting and working with quantities. With these beads, it was no longer necessary to count on fingers. From the earliest beginnings of processing, the trend has been toward reducing mental and manual effort.

a. Abacus. The strung beads led to the development of the abacus (fig 13). The origin of the abacus remains obscure. Many nations claim to have invented it; however, its earliest home is believed to have been Babylon or Egypt. Whatever its origin, however, the abacus has withstood the test of time, since it is still being used in several parts of the world. Arithmetic is performed on an abacus by moving the appropriate counter beads up or down on the proper wires. Each counter bead below the bar, when moved up, represents 1; each above it, when moved down represents 5. The numbers printed above the abacus in figure 13 indicate what each position of the beads on the wires represents. The abacus was used mostly for addition and subtraction, but many people also achieved competence in using it for multiplication and division as well.

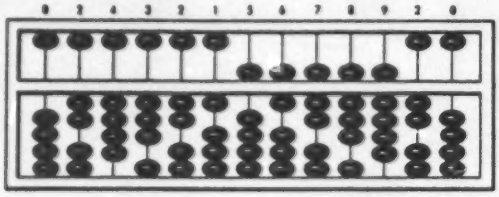

Figure 13. Abacus.

(1) In multiplication, successive additions of a value are made. To multiply 3 times 4, for example, either 3 is added to itself four times (3 + 3 + 3 + 3 = 12) or 4 is added to itself three times (4 + 4 + 4 = 12). In either case, the product of 12 is obtained.

(2) Division is executed by successively subtracting the divisor from the dividend until the remainder is equal to zero or is less than the divisor. The number of subtractions determines the quotient. For example, if we wish to divide 12 by 3, we use the following procedure:

12 - 3 = 9	1	
9 - 3 = 6	1	Number of subtractions
6 - 3 = 3	1	
3 - 3 = 0	1	
Quotient	4	

b. Napier's bones. In 1614, another advancement toward the mechanization of arithmetic operations was developed by John Napier. A group of numbered rods, each rod serving as a multiplication table for one digit, was called "Napier's bones." When multiplying, the rods were lined up in order, and the answer was found by reading across at the proper level. Napier divided the rods into nine squares. The top square held a decimal digit (that is, 1 through 9) and represented the product of its multiplication by 1. Each of the remaining eight squares was divided diagonally and held (from top to bottom) the product of the digit in the top square multiplied by 2, 3, 4, 5, 6, 7, and 8, respectively. Once the set was completed, the product of any two numbers could be obtained by adding the values pertaining to them diagonally. Figure 14 shows the rods for multiplying 1, 2, 3, and 5. As an example, let us multiply 4 times 235. Using Napier's bones, we identify the multiplier 4 in the fourth square of the left rod. The multiplicand 235 is shown on the remaining three rods. The product is obtained by adding diagonally, from the right, the values in the fourth square of each of the rods of the multiplicand.

Unit's position--the contents of the right diagonal column--0.
Ten's position--the sum of the second diagonal columns--2 + 2 = 4.
Hundred's position--the sum of the third diagonal columns--8 + 1 = 9
The product is 940.

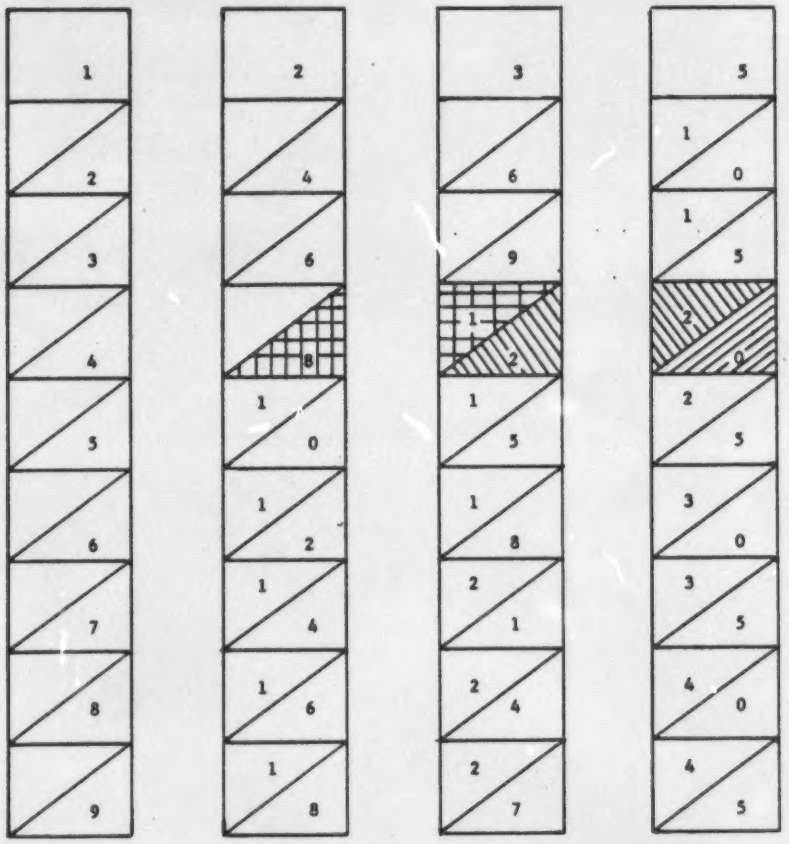

Figure 14. Napier's bones.

c. Pascal's calculator. In 1642 Blaise Pascal invented the first digital device employing mechanical means rather than hand operation in arithmetic processes. Some of the basic principles and mechanisms of this adding machine are still used today. Pascal used a wheel with 10 points to represent the numerals 0 through 9 (fig 15). A quantity was entered by turning each wheel until the appropriate numeral was alined with an index. Addition was then performed by rotating the proper wheels, the number of points corresponding to the value being added. As an example, to add 12 to a stored number 36, the unit's position wheel would be rotated two places (from 6 to 8) and the ten's position wheel, one place (from 3 to 4), thus giving the sum 48. The most important advance of Pascal's machine was the ability to carry numbers automatically to the next higher position; for example, to carry a 1 from the unit's position to the ten's position when adding 6 to 7.

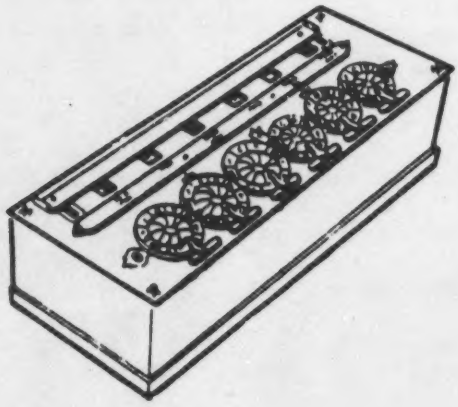

Figure 15. Pascal's calculator.

d. Jacquard's loom. This device, invented in 1745 and perfected in 1801 by Joseph Jacquard of France, was the first machine to accept information recorded on punched cards (fig 16). A series of punched cards were attached together in the form of a loop that rotated past a reading mechanism. This reading mechanism translated the punches and thus activated a thread-selecting mechanism that selected the various color threads at the proper time as the machine was weaving a certain pattern. Thus, the first application of automatic digital process control was used to control a loom.

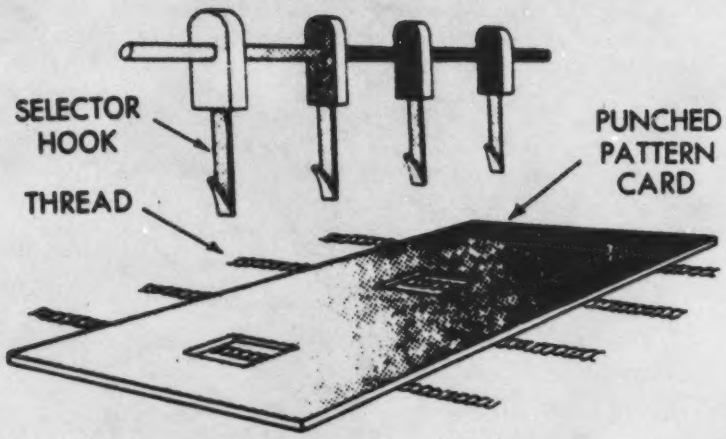

Figure 16. Jacquard's loom.

e. Babbage analytical engine. This device (fig 17) incorporated three elements that are used in computers today: a store for holding information, a mill (arithmetic unit) to work on the information, and a control to govern automatically the actions of the mill. Upon completion of an operation, Babbage's design also called for the mill to request automatically the next operation in sequence. Babbage's analytical engine merits special mention because, in theory, it embodied most of the basic principles of today's electronic computers. Most significant was the fact that the device would automatically carry out a predetermined sequence of mathematical operations and make limited decisions based on the results of its own computations.

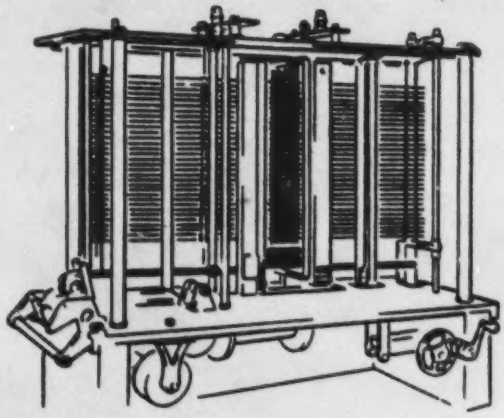

Figure 17. Babbage's analytical engine.

f. Boolean algebra. One of the first persons to express logic (the science of the formal principle of reasoning) in mathematical terms was George Boole in England in 1847. He prepared a pamphlet in which he expressed logic in terms of 1's and 0's and later introduced rules for addition, subtraction, multiplication, and division. Boolean algebra is used today in designing computer circuitry and in determining the most logical circuit arrangements.

g. Hollerith code. Dr. Herman Hollerith was engaged by the US Government in 1880 to devise a faster and more efficient method of tabulating the census. The tabulation for the 1880 census had taken 7-1/2 years to complete. In 1887, Hollerith completed a system using 3- by 5-inch cornercut cards divided into 1/4-inch squares, a punch, pin press, electromagnetic counters, and a sorting box. This device was capable of speeds of 50 to 80 cards a minute. Hollerith's punched card equipment was used in the census of 1890 and reduced the tabulation time to 2-1/2 years. Punched card equipment was used to process data automatically before computers were developed. Today, we find punched cards used as one type of input to computers.

18. COMPUTER GENERATIONS.

a. Vacuum tube. One of the most important developments that made high-speed computers possible is the diode vacuum tube invented in 1904 by an Englishman named Fleming. The diode tube is a rectifying device that changes alternating current to direct current by passing current through the tube in only one direction. With the invention of the vacuum tube, all the components had been invented and all the concepts had been thought of to make high-speed computers possible.

b. First practical automatic computer. In 1944, the Army sponsored research at Harvard University on the first practical computer, called the Harvard Mark I. This computer did not have vacuum tubes; however, it did have the following characteristics:

(1) It operated electromechanically at speeds of 3/10 of a second for addition or subtraction.

(2) It stored numbers consisting of 23 decimal digits.

(3) It required standard punched cards for input.

(4) It was the first machine capable of performing long sequences of arithmetical and logical operations.

(5) It could accommodate an externally stored program.

c. Electronic numerical integrator and calculator (ENIAC). This was the first electrical digital (high-speed) computer. In 1945, Dr. Mauchly and J. Presper Eckert used the facilities at Moore School of Electrical Engineering to design and build the ENIAC. Some of the characteristics of this computer follow:

(1) It was the first machine to use electronic tubes for calculating.

(2) It was programed at first by means of a plugboard.

(3) It could execute 5,000 additions a second, using 10 decimal digit numbers.

93 d. Computer development since 1947. Since 1947 the computer development has been classified into three different generations (fig 18).

(1) First generation. The introduction of business-type computers in the mid-1950's marked the beginning of this generation, although technically this generation was characterized by the vacuum tube. The first-generation computers required large amounts of floor space and electric power because many thousands of vacuum tubes were used. Reliability was very low because of the relatively short lifespan of a tube system, and strict environmental control (air conditioning) was necessary. These computers normally operated at speeds measured in seconds and milliseconds (thousandths of a second). Only a few first-generation computers are still in use today.

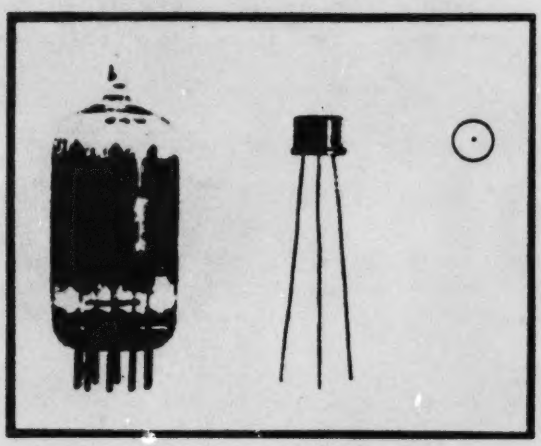

Figure 18. Computer generations.

(2) Second generation. The development of the transistor in 1957 provided the technology for second-generation computers. The transistor, known as solid-state circuitry, has brought about improved speed and reliability for the computer while decreasing the machine's size, power requirements, and air-conditioning requirements. Second-generation circuitry is mounted on printed circuit boards that are easily interchangeable when a particular circuit fails. Shortly after the introduction of the transistor, a more suitable storage medium, the magnetic core, became available. The use of transistors for circuitry and magnetic cores for storage permits second-generation computers to operate at speeds measured in microseconds (millionths of a second). Many computers in operation today are of the second-generation variety.

(3) Third generation. In 1964, the third generation (and our present-day computers) was introduced. These computers used microcircuitry to replace the second-generation transistors. This microcircuitry is called monolithic integrated circuitry, or "chips," that are one-twentieth of an inch square. One of these circuits can perform the functions of 20 transistors, 18 resistors, and two capacitors. Some of the wires used to interconnect these chips are one-third the diameter of a human hair. The use of third-generation circuitry permits increased reliability and speed at a lower cost. In addition, little or no air conditioning is required. Some third-generation computers operate at speeds measured in nanoseconds (billionths of a second). Obviously, it has also been possible to reduce the space required in central processing units.

19. CLASSIFICATION OF COMPUTERS BY APPLICATION.

a. At present there are three classes into which we can place any computer. These are small scale, medium scale, and large to giant scale. We do not necessarily mean physical size when we speak of size; although, a large-scale computer is usually larger in physical size than a medium or small-scale computer. By size we mean the capacity of the system to store data, its input and output facilities, and its general ability to perform large jobs. Storage capacity of a computer is expressed in terms of the number of bits (binary digits), characters, or words the device can store at one time. To compare memory devices effectively it is necessary to convert to a common unit of measurement, bearing in mind such variable factors as the number of bits per character and the number of characters per word. In one system, for example, a 4,096 word memory is the same size as a 24,576 character memory, and the same size as a 155,648 bit memory. Storage capacity of digital computers is expressed in thousands of bits. Considering these requirements, the classification of computers by their application is reflected by the data listed below.

(1) Small.

(a) 2-10K bit storage.

(b) $750 - $7,500 monthly rental.

(c) $250,000 purchase price.

(2) Medium.

(a) 10-32K bit storage.

(b) $7,500 - $18,000 monthly rental.

(c) $250,000 - $500,000 purchase price.

(3) Large to giant.

(a) Greater than 32K bit storage.

(b) Greater than $18,000 monthly rental.

(c) Greater than $1 million purchase price.

b. Generally, the purchase price can be estimated by multiplying the monthly rental cost times 42 (the estimated life of the computer).

c. The computers that will be used in processing military data will usually be the general-purpose, digital, business-type computers. The size, of course, will vary according to the job involved.

SECTION VI. STORAGE DEVICES

20. GENERAL. Storage or memory is a place where the computer stores data for ready reference while it is processing a problem. The speed and efficiency with which an automatic data processing system can process data depends, in part, upon the design and use of its storage system. But the proper evaluation, selection, and use of a storage system is a very difficult task. This is due to several factors. First, it is difficult to specifically state storage requirements for a system because such requirements are continually subject to change. Second, the evaluation and selection of the storage is complex since this must be done on the basis of several characteristics and a wide variety of application requirements. Even the most informed users find the task of storage evaluation, selection, and proper use very complex. If a person knows nothing or very little about storage, this task becomes nothing more than guesswork. The material contained in this instruction is an attempt to provide a little insight into the vast subject of storage. We will examine the types of storage, the general characteristics of storage, and some of the storage devices used in automatic data processing systems today.

21. TYPES OF STORAGE. Just as man's mind enables him to recall and re-create any fact that he must use or will need, automatic data processing systems have storage devices that store facts in machine language and recall them rapidly when they are needed. Since scientists do not know how the mind selects storage locations within the brain, such a storage system cannot be completely duplicated in automatic data processing systems. The system developed divides all storage into separate storage locations of convenient size. These storage locations are either addressable or nonaddressable.

a. Addressable storage. In addressable storage, each storage location has a specific number assigned to it. This number is called its address. Each digit or series of digits is specifically located in an addressable place just as your house number specifically locates your house on a particular street. Each program instruction that requires the use of information stored in addressable storage must make reference to its exact location through the use of its address.

(1) Each mailbox used in a post office has a number assigned to it (fig 19). The upper right-hand mailbox is number 105. This means that all the mail addressed to box 105 goes there. The lower left-hand mailbox is number 118, and all the mail addressed to box 118 goes into it. Each box can hold only a certain number of letters.

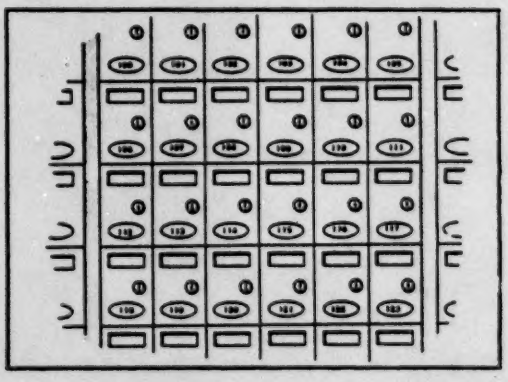

Figure 19. Post office mailboxes.

(2) The arrangement of the mailboxes can be compared to addressable storage. Each mailbox is analogous to a storage location. Each storage location holds only a certain number of characters—no more and no less. Also, each storage location has a number—its address—assigned to it. The address of any storage location is unique. There is no other address for that storage location, and no other location has that same address. Thus, when information is called for from storage location 620, only the data in storage location 620 is delivered. The same is true for any of the other storage locations.

(3) When we designate a storage location by a numerical address, it is called absolute addressing. Thus, the numerical designation of the storage location is its absolute address. There are two other ways of designating storage locations. They are by symbolic addressing and relative addressing. In symbolic addressing, the storage location is designated by a specific name or tag; e.g., TOTAL, PAY, NAME, or similar label. This name, tag, or label is the symbolic address. A relative address is an extension of a symbolic address. The relative address is a label used to identify a storage location with respect to its position preceding or following other locations; e.g., TOTAL + 3, PAY + 7, NAME + 10.

(4) The address of the storage location is very important because whenever the data located there is needed it can be called for by its address and delivered rapidly and accurately.

b. Nonaddressable storage. This type of storage, as its name implies, does not have each storage location addressed. When data stored in nonaddressable storage is needed, the computer must search each storage location until it finds the data desired. The computer, therefore, does not have direct access to such data. It cannot go directly to the storage location and retrieve the data stored there. This is the opposite of addressable storage.

(1) This type of storage can be compared to post office boxes without numbers. Let us assume that you are to receive your mail in a post office box in a large post office. This post office has several thousand unnumbered boxes on which no names appear. Moreover, your mail is not placed in the same post office box each day. Thus, the only way you can find your mail is to search each post office box in turn until you find it. You can imagine the amount of time this would take. This type of storage is called nonaddressable.

(2) If your mail were placed in a box having a number and it remained in exactly the same location, you would have direct access to it. Thus, it would be addressable.

22. GENERAL CHARACTERISTICS OF STORAGE. Information is fed into addressable or nonaddressable storage in machine language. Although information is stored in machine language, it is not necessary to manually convert all alphanumeric characters to machine language. The computer has the circuitry necessary to perform this operation. Besides the fact that information is stored in machine language, there are certain other general characteristics of storage that must be known.

a. Access time. A common method of classifying and evaluating storage is by access time. Access time is the length of time that elapses between the instant a call is made for data from storage and the instant the data is delivered in the place where it is needed. In reality, access time is the amount of time required to initiate electronic circuitry to contact a specific storage location and transmit the information stored there to some other place within the computer where it is needed. Access time appears to be instantaneous, but it can be measured in milliseconds (thousandths of a second), microseconds (millionths of a second), nanoseconds (billionths of a second), and picoseconds (trillionths of a second). Although such measurements appear infinitesimal and insignificant, they are vitally important when multiplied by the number of times that data must be retrieved from storage. By such measurements, the length of time needed to solve a data processing problem can be determined. As a means of trying to visualize these speeds, we can make the following comparisons:

(1) A millisecond is to a second what a second is to 16 minutes.

(2) A microsecond is to a second what a second is to 11-1/2 days.

(3) A nanosecond is to a second what a second is to 31-1/2 years.

(4) A picosecond is to a second what a second is to 315 centuries.

b. Erasing. A data processing term which is associated with storage is erasable. This term means that the data currently in storage can be removed or destroyed and replaced by new data.

(1) If data can be erased by writing new data over the old data, the storage device is said to have a destructive read-in capability.

(2) If data is erased from storage by reading out of storage, the device is said to have a destructive read-out capability. If data is not erased from storage by the read-out process, the device is said to have a nondestructive read-out capability. At the present time, computer storage devices available have a nondestructive read-out design.

c. Volatile—nonvolatile. Some storage devices are said to be volatile. Volatile means that the information stored in the device is lost or destroyed if the electric power supply to the machine is shut off. Other storage units are said to be nonvolatile. Nonvolatile means that once information is stored it is retained until it is deliberately removed. Even if the electric power supply is turned OFF, the information is retained in the storage device. Most storage devices used in automatic data processing today are nonvolatile.

d. Capacity. This term identifies the amount of information a storage device can hold. This amount is expressed in characters, bits, or words. Capacity varies with type of storage.

e. Cost. The cost of storage devices varies considerably. Cost is usually expressed in cents per bit. As you study the various devices you will note that the faster the access time of the storage device, the higher its cost.

23. CENTRAL PROCESSING UNIT STORAGE. Central processing unit (CPU) storage is also called internal storage or high speed storage. The storage is built into the CPU of a computer. The devices used most often for the internal storage unit of a computer are thin film, magnetic core, and magnetic drum. These three devices have certain common characteristics. They are addressable, have very fast access time, have limited capacity, and are very expensive.

a. Thin film. Thin film storage is the most recently developed type of storage to be placed or used as the internal storage unit for computers. This storage device has the fastest access time.

(1) Data can be retrieved from thin film storage at a speed measured in nanoseconds. The access time for thin film storage for one computer is only a few nanoseconds. Perhaps the most significant characteristic of thin film is its extremely fast access time.

(2) Thin film is ferromagnetic film a few millionths of an inch thick and about the size of a postage stamp. This ferromagnetic film is made by depositing vapors of iron, nickel, cobalt, or other ferromagnetic metals or their alloys on a suitable substrate such as thin plate glass (fig 20). Small dots are deposited on the glass or insulating base by a vaporization process. A plate containing holes a millionth of an inch in diameter is placed over the film, and the various metals are heated. As the metal vaporizes, it travels through the plate and is deposited on the film. Thousands of bits may be stored on a 1-square-inch plane.

(3) The direction or polarity of the magnetized spot can be represented by a magnetic dipole which has two stable states parallel to the preferred direction. They are the unit and zero states. Three wires are required for read-write operations. Each plane of thin film memory is sandwiched between two printed circuits containing the wires for the read, write, and sense operations,

(4) The size of thin film allows computer manufacturers to build computers which are smaller in physical size, but greater in storage capacity, than earlier computers. Thin film memory requires no threading of wires through holes and, therefore, can be constructed more easily by printed circuit techniques. This facilitates mass production. Less electric power is required to energize thin film storage; but the savings obtained by using less power cannot pay for the cost of such storage, which is very high.

(5) When thin-film planes were first made, they were constructed by hand. If one bit was not up to standard, the entire plane had to be discarded. Consequently, the initial price of a plane was about a dollar per bit. With new techniques of vacuum depositing, the present cost has brought the thin-film memory into a practical price range. Undoubtedly, there will be further improvement and miniaturization of the films in the future. Future devices hold a great deal in store. Since the size of a particular computer memory often is based on the practical cost for the system, and since it is desirable to have more memory than is made available, a cheaper method of primary storage is constantly being sought. However, data processing equipment users are not willing to sacrifice speed for a reduction in cost.

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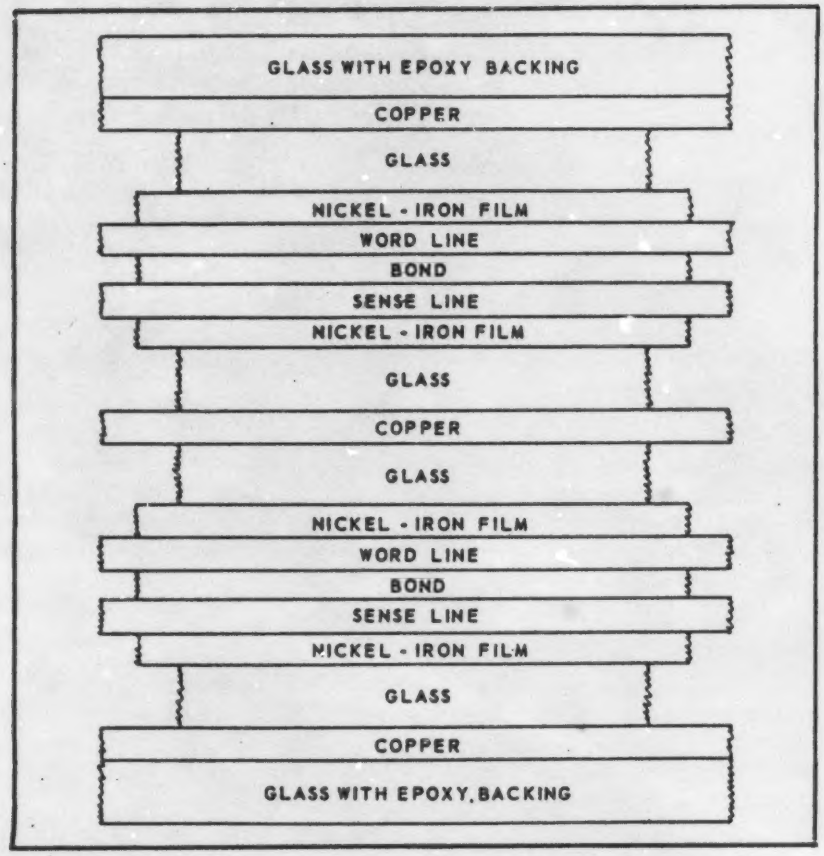

Figure 20. Thin film memory plane.

b. Magnetic core. Among the many advantages of magnetic core storage are high speed access, ease of maintenance, and dependability.

(1) Description. Magnetic cores are tiny, doughnut-shaped iron or ferrite rings between one-sixteenth and one sixty-fourth of an inch in diameter. These tiny cores are strung on frames in matrix fashion with one core for each binary digit (bit). Several of these bits are used to depict a number or letter. When current of sufficient magnitude is passed through the wires laced through a core, it becomes magnetized. The magnetic polarity of each core depends upon the direction in which the electric current flows. The core's polarity determines whether it is read as a binary 1 or 0. A magnetic core remains in its magnetic state until deliberate action is taken to change it. Computers which have magnetic core memory have the destructive read-in and nondestructive read-out features. They also are nonvolatile.

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(2) Core selection. By passing two wires through the center of a magnetic core and sending half of the required current needed to give the desired polarity to the magnetic core through each wire, it is possible to select and magnetize a desired core. (These wires are numbered (1) through (8) in the magnetic core matrix (fig 21).) If only one wire is carrying current, the polarity of the core cannot be changed. Thus, any specific core strung on wires within the matrix structure can be given the desired polarity by sending half of the desired current through a horizontal wire and the other half through a vertical wire. Only the core at the intersection of these two wires has its polarity changed. The reversal in the direction of the magnetic field simultaneously changes the binary symbol stored there from 0 to 1 or from 1 to 0. In the same illustration, you can see that when one current is passed along wire (4) and another current is passed along wire (5), only the core at the intersection of these two wires (indicated by "X") has the polarity changed. This is the only core at the intersection of these two wires.

(3) Reading. Examining or reading information from a magnetic core is accomplished by means of a sensing wire (fig 21). This wire is laced through each core of the matrix. To read data from a magnetic core, the core is selected to set to 0. A core having the required polarity for a binary 1 will have its condition changed by this action. This induces a signal in the sensing wire. However, a core having the polarity of a binary 0 will not be changed by this action, and no signal will be induced in the sensing wire. The induced signal in the sensing wire operates the reading circuitry. Since this read operation changes the condition of the magnetic core from 1 to 0, it temporarily removes or destroys data in memory. But the reading circuitry is so designed that it replaces this information automatically by the use of an inhibit wire. This wire prevents restoration of 1's in all but those cores whose polarity was changed in the sensing operation. The illustration in figure 21 shows how the number 4701 is stored in magnetic core storage arranged in matrix fashion.

(4) Access. Magnetic core storage has rapid access to stored data. One of the fastest magnetic cores now available has an access time measured in nanoseconds; however, access time for magnetic core storage ranges anywhere from milliseconds to nanoseconds.

(5) Address. The matrix construction of the magnetic core storage facilitates addressing any storage location. Information is delivered from that storage location to the register in the minimum amount of time.

(6) Capacity. The storage capacity of magnetic core storage when used as CPU memory ranges anywhere from a few hundred to over a million characters. Most systems are expandable.

(7) Disadvantages. Magnetic core storage falls into the high cost category when we compare its cost against the cost of other types of internal storage. A single plane of magnetic core matrix may cost several hundred dollars. There are many such planes in a system. Newer methods of mass production in their manufacture, including printed circuits, have cut and continue to cut the cost of a plane of magnetic core storage.

c. Magnetic drum. Another high speed storage device used in memory is the magnetic drum. A magnetic drum (fig 23) is a precision built metal cylinder coated with a highly magnetizable material. Data and instructions are stored on the outer surface of the drum in the form of magnetized spots. The drum revolves at high speed under a series of read-write heads. Each read-write head is a tiny magnetic coil (fig 22). In the writing operation, current passing through the coil sets up a magnetic field. This places a magnetic spot on the surface of the drum. In the reading operation, a magnetized spot passing under the read-write head causes a small electrical current to flow through the head core. As this electrical current cuts across the winding, it generates an output signal. This signal is then transferred to the operating circuitry.

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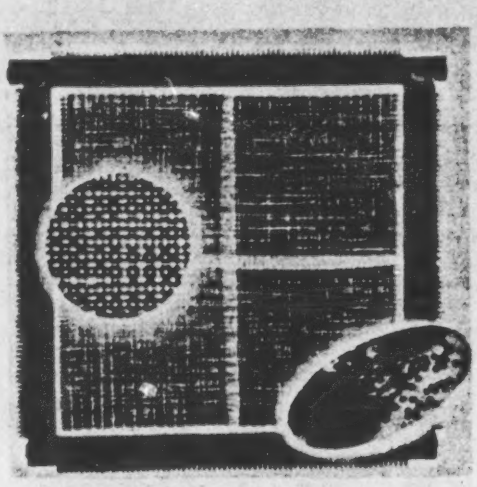
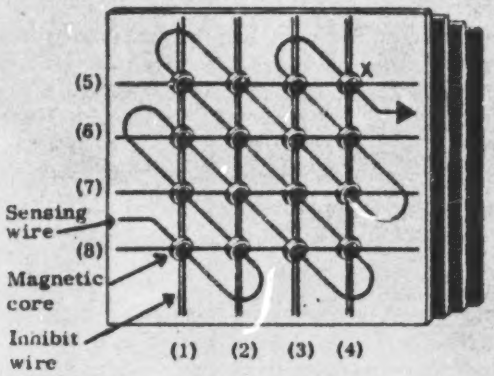
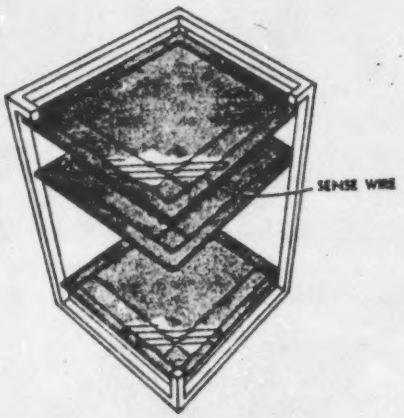


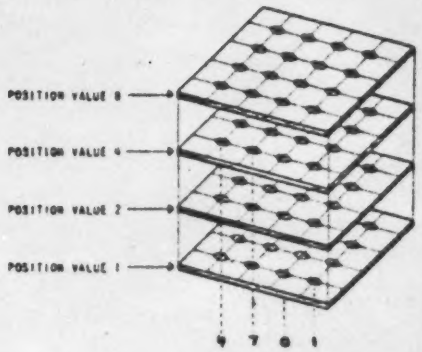
Magnetic Core Plane.



Magnetic Core Matrix.



Sensing Wire.



Storing the Number 4701 in Magnetic Core Memory.

Figure 21. Magnetic core.

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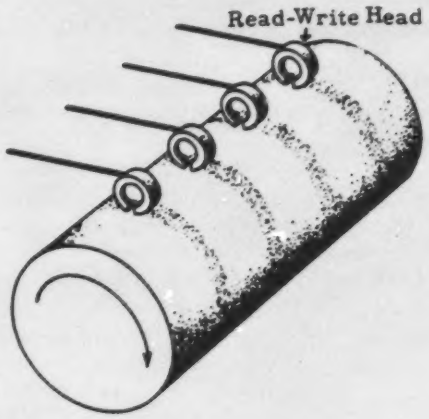
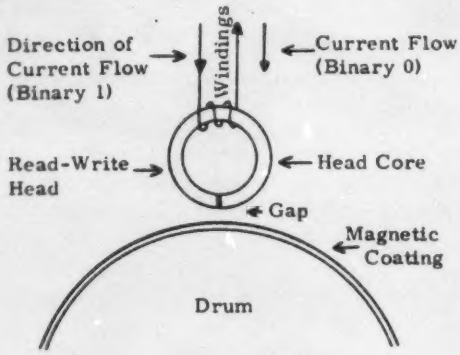
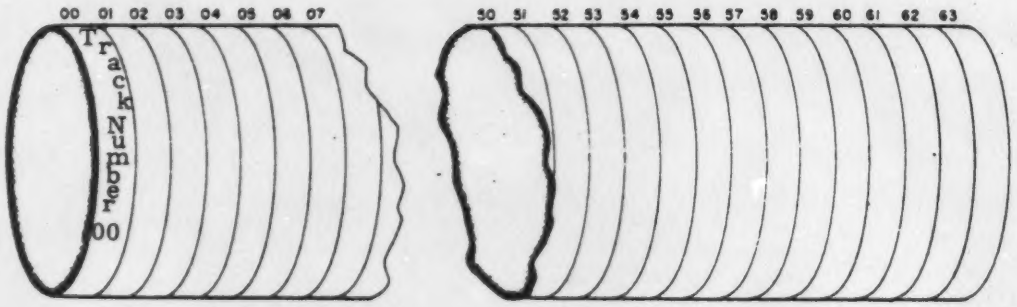


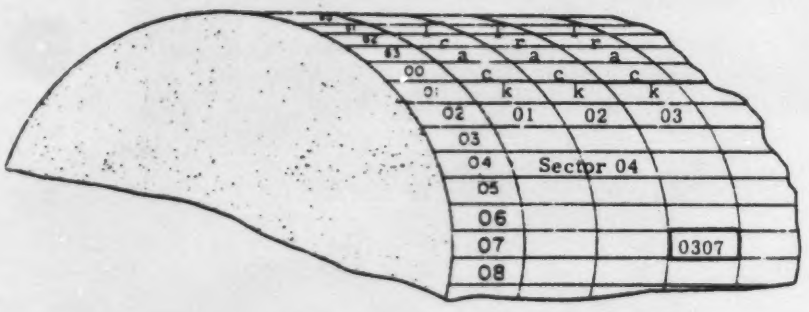
Magnetic Drum.



Read-Write Head.



Magnetic Drum Showing 64 Tracks.



Magnetic Drum Showing 64 Sectors Per Track.

Figure 22. Magnetic drum.

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(1) Storage system. A single magnetic drum is usually sufficient for the CPU memory. If necessary, however, multiple drums may be used. Each drum is divided into a series of numbered, parallel tracks which circle the surface of the drum (fig 22). Each drum is also divided into numbered sectors which run lengthwise across the surface of the drum (fig 22). Thus, each item of information is stored in a specific sector of a particular track. For example, if a person's service number were stored in sector number 07 of track number 03 of the drum, it would be stored in storage location 0307 as shown in figure 22. This would be its address.

(2) Access time. Because of its characteristic of continuous rotation, information can be written into or read from a storage location when the desired address passes under the read-write head. Thus, the access time for reading data from storage depends upon the position of the storage location in relation to the read-write head. For this reason, access time for reading data stored in a storage location on a magnetic drum ranges from a minimum to a maximum access time. The minimum access time is obtained when the storage location containing the desired data passes under the read-write head at the precise moment the call is made for that data. Thus, it can be instantly delivered. The maximum access time is required when the storage location containing the desired data has just passed under the read-write head immediately prior to the call for the data. The drum must then make a full rotation before that data is again in a position where it can be read. For the purpose of computing the time required to complete a data processing operation using a magnetic drum, the average access time is used. This is computed by taking one-half of the maximum access time. Average access time, then, is one-half of the time required for the drum to make or complete one full revolution. There are other factors which affect the access time for data stored on a magnetic drum. They are the physical dimensions of the drum, speed of rotation, number and types of read-write heads, and arrangement of data. Nevertheless, the average access time for magnetic drums ranges from several hundred microseconds to more than a hundred milliseconds, depending upon the make of drum.

(3) Storage capacity. Magnetic drums vary greatly in capacity and operating speeds. These storage drums also vary in diameter and length. They rotate at various speeds, measured in thousands of revolutions per minute (RPM). Storage capacities range from several thousand to a million characters.

(4) Features. Magnetic drum storage is nonvolatile. These storage devices have the destructive read-in feature as well as nondestructive readout feature.

(5) Cost. The magnetic drum is a compromise between speed and price. Most magnetic drum storage devices have slower access time than other types of storage devices used for internal storage. At the same time, however, they also have a lower cost. Because of its cost, the magnetic drum remains the most economical solution to some problems.

24. BULK STORAGE. Bulk storage is the term used to identify storage devices which can store large volumes of data—usually in the millions of characters. Because of its storage capacity, bulk storage plays an important role in processing methods previously discussed. An understanding of this role can best be obtained by discussing bulk storage in two categories: addressable bulk storage and nonaddressable bulk storage. Bulk storage is analogous to the files or file cabinets used in an office. Man has a brain that does his processing. The file cabinets hold data that supports man's main storage located within his brain. No instructions can be executed within the file cabinets, nor can any data be processed there. The same is true for bulk storage. In order to execute instructions or process data stored in bulk storage, the instruction or data must first be brought into the main computer storage located within the CPU. Bulk storage is often referred to as external

storage. External means that it is outside the CPU even though it is connected to the CPU and controlled by it. For our purpose, we use the term "bulk storage."

c. Addressable bulk storage. Addressable bulk storage devices have certain unique characteristics. They are physically located outside the CPU and serve only as an adjunct to high speed memory. Each of the storage locations is addressable. These devices can hold millions of characters of information and provide a medium to fast access time to this stored data. This access time is not as fast as that used for CPU storage, but it is within the millisecond range. Addressable bulk storage devices have access to any of the large amount of data stored there at any time, in any sequence, and in an acceptable amount of time. Thus, they lend themselves to direct access processing. Addressable external or bulk storage is characterized by the following: it is addressable, it has a medium to fast access time, and it has a medium cost and large storage capacity. This large storage capacity has a distinct advantage for online files and data banks. It was not until 1956 that an addressable bulk storage device, which to a degree met the essential requirements for direct access processing, was developed. Since that time, progress has been made in perfecting this type of storage for use in direct access processing. Addressable bulk storage devices which can be made available and will operate at electronic speed are costly. Magnetic core storage and thin film could be used, but the cost of such storage would be prohibitive because of the large volume of characters which must be stored. Addressable bulk storage devices available today at moderate costs use mechanical features. Such features considerably slow down access time. For example, magnetic disks hold an extremely large volume of data at a relatively low cost to the user, but these storage devices require the use of mechanical devices to operate them. Thus, the devices operate at speeds much slower than the electronic speeds of the computers. When this difference is considered, the result is a waste of valuable computer time. The addressable bulk storage devices currently available use either magnetic drums, magnetic disks, or magnetic cards. Let us examine some of these devices.

(1) Magnetic drums. General storage drums vary in size, operating speeds, and address systems. Usually, general storage drums have a storage capacity in millions of characters. These devices operate at a speed of a few thousand RPM. Access time varies with the size and operating speed of the device. The average access time for general storage drums is in the low millisecond speed. Most computer systems are so designed that several of these general storage drums can be attached to them.

(a) The storage system of the general storage drum differs with manufacturers' products, but it is usually relatively simple in design. The surface of the drum is usually divided into tracks. These tracks are further divided into addressable groups consisting of several tracks. This allows data recorded on the several tracks to be read in parallel rather than in series. These tracks are further divided into addressable records.

(b) Record length on the general storage drum may be fixed or variable, depending upon the need of the user. Some manufacturer's products, however, use only a fixed record length in particular models of the general storage drum. Even on drums using a fixed record length, the length of the record is still determined by the data to be processed.

(c) The general storage drums have been used for a number of different applications. They have been used to store continuing records (such as inventory balances, schedules, masses of unsorted data, and tables and rates.)

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(2) Magnetic cards. A type of addressable bulk storage which was developed recently and placed on the market is a device which uses magnetic cards. Magnetic card storage is generally used when a large storage capacity is needed and there is a relatively small amount of processing activity. Let us examine two of these devices—the card random access memory (CRAM) unit and the data cell.

(a) CRAM. The CRAM device (fig 23) uses magnetic cards that are 14 inches long and 3-1/4 inches wide. Each card has seven data recording tracks with each track addressable for reading and writing data. On each track 3,100 alphanumeric characters can be stored. This gives each card a storage capacity of 21,700 alphanumeric characters.

1. Each CRAM file can handle a deck of 256 cards. Newer models of the CRAM unit use a deck containing more cards, but the unit works on the same principle. A deck of magnetic cards is kept in a cartridge which can be interchanged with the deck already in the unit. This change takes approximately 30 seconds. Since each card holds 21,700 alphanumeric characters and each file contains 256 cards, this gives each cartridge a storage capacity of more than 5-1/2 million characters. Thus, the CRAM unit provides large storage capacity with each removal and mounting. In addition, several of these devices can be attached to a single computer.

2. When the cartridge is mounted on the unit, each magnetic card is suspended from two gating rods (fig 23). The cards are individually selected by eight electronically controlled two-position rods. With these eight rods, 256 different position combinations can be made. Each of the 256 cards in a deck has a unique binary notching configuration. The position of the electronically controlled rods permits the correct card to be released from the deck when selected. For example, if card number 8 is addressed or called for by the computer, the eight 2-position rods are automatically set to the binary number of 8. This allows the gating rods to open, and the cards with the notching configuration of 8 are released from the deck.

3. Once a specific card has been called for by the computer and the rods in the unit have been properly set, the magnetic card is dropped from its hanging position (fig 23). To keep the cards separated so that they may drop freely, 256 jets of air are used. After the card has been released, it is pulled by a vacuum onto a rotating drum which quickly accelerates to a speed of 400 inches a second. It is important to note that while the card is dropping to the drum, the computer is free to perform other processing. This may include issuing instructions to another magnetic card unit. To signal the computer that the card has reached the drum and is in position to transmit or receive data, a series of photoelectric cells are used.

4. In the drum, the card passes under seven read-write heads—one for each recording track. The read head automatically checks the accuracy of the recording as well as its normal operation of reading the stored information on the card. The card travels at 400 inches per second and the data is recorded at 250 characters per inch. This provides a transfer rate of 100,000 characters per second.

5. After the read-write operation, the magnetic card is returned to a position on the eight rods. Its position on these rods is irrelevant since the card selection is made by the eight position rods. The return is accomplished by a tunnel of moving air. Once the card is back into position, it is ready to be selected again.

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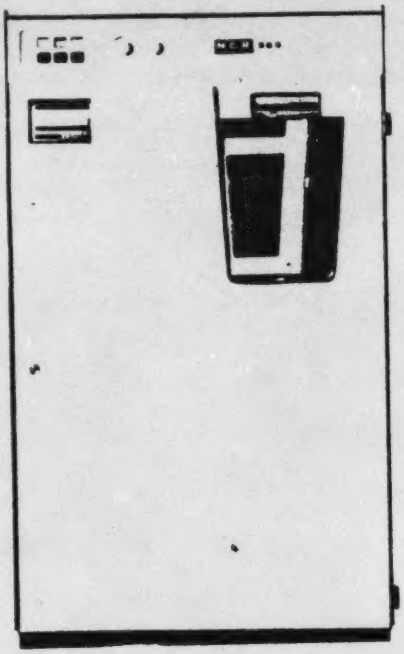
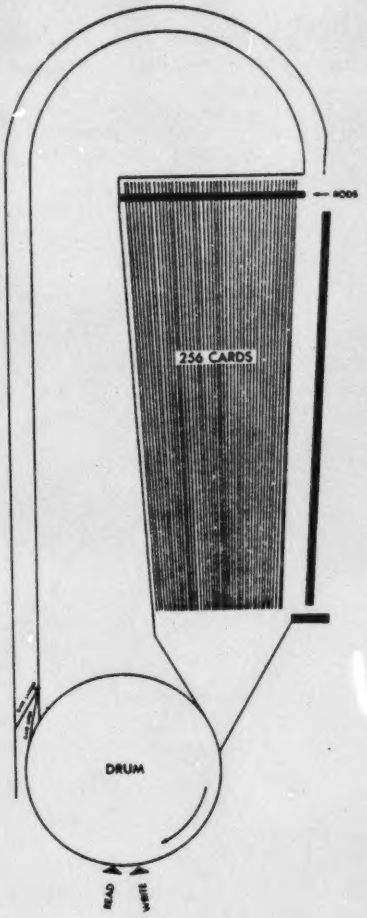


CRAM Unit.



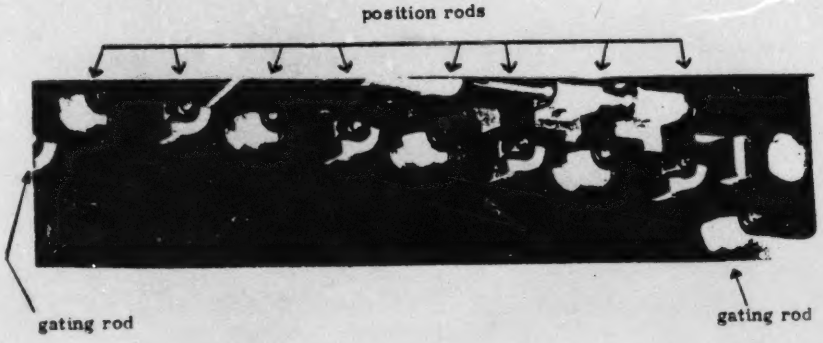


Figure 23. CRAM device.

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(b) Data cell. The data cell was developed by International Business Machines. The data cell (fig 24) stores several hundred strips of approximately 2 by 12 inches of magnetic film. Ten of these strips grouped are called a subcell. Twenty subcells in turn make up one data cell. Individual strips can be retrieved by the device and information stored on the 200 tracks available on each strip.

1. The cell drive can accommodate up to 10 data cells and is able to position the selected cell under the retrieval mechanism. Cells may be removed and replaced with others containing different files. Each of the drives (fig 24) has a capacity for storing up to 40 million characters.

2. Reading or writing occurs on the strip by rotating the circular array to one of 200 discrete subcell positions. This positions the strip to be selected beneath a selection mechanism. The array may rotate in either direction. The strip containing the data to be read or written is extracted by a pickup head which selects the proper strip and places it around a revolving drum. The strip is then read by a series of read-write heads. During the restore cycle, the rotation direction of the drum is reversed and the strip is returned to its original location in a subcell.

3. The data cell drive economically extends online direct access storage capabilities to a volume of data beyond that of other storage devices.

(3) Magnetic disks. In magnetic disk storage (fig 25) a series of metallic disks arranged in much the same manner as musical records in a jukebox serve as the storage medium. The magnetic disk is a thin metal disk varying from approximately 14 inches to 2 feet in outside diameter. The disks are coated on both sides with a ferrous oxide material. Information is recorded in magnetic spots on the top and bottom of the disks by means of read-write heads. Recent improvements in magnetic disk storage have increased the storage capacity as well as the number of read-write heads for faster access. The number of access arms per disk surface and the number of read-write heads per access arm will vary with the make of the disk unit. Access speed of the disk depends upon the number of these arms, heads, and speed of rotation. The addressable bulk storage devices which use magnetic disks are divided into two types: the large magnetic disk and the disk pack. Let us consider an example of each type.

(a) Large magnetic disks. On one large magnetic disk file storage device, every track of each surface has an individual read-write head. These read-write heads operate by electronic switching which provides greater reliability. The read-write heads seek out a specific storage area and read the data from it or write the data into it in an average access time of 17 milliseconds. A single four-disk module has up to 100,000 addressable locations, depending upon the data segment size. Regardless of the number of storage locations, a four-disk module will hold a maximum of 9.6 million alphanumeric characters. From 1 to 50 of these modules may be used to store up to 480 million characters.

1. The large magnetic disk system uses a 7-decimal address which is sequential. This feature provides ease in record addressing, filing, and files maintenance. Through selectable data segment sizes, the magnetic disk system provides variable record length capabilities. Data segment sizes are available in 96-, 240-, and 480-character lengths. This system reads and writes up to 10 sequential data segments with one command. Other advantages of this magnetic disk system include an automatic check to assure valid data recording, extremely fast file scanning and record sorting abilities, and rapid loading and dumping to or from magnetic tape.

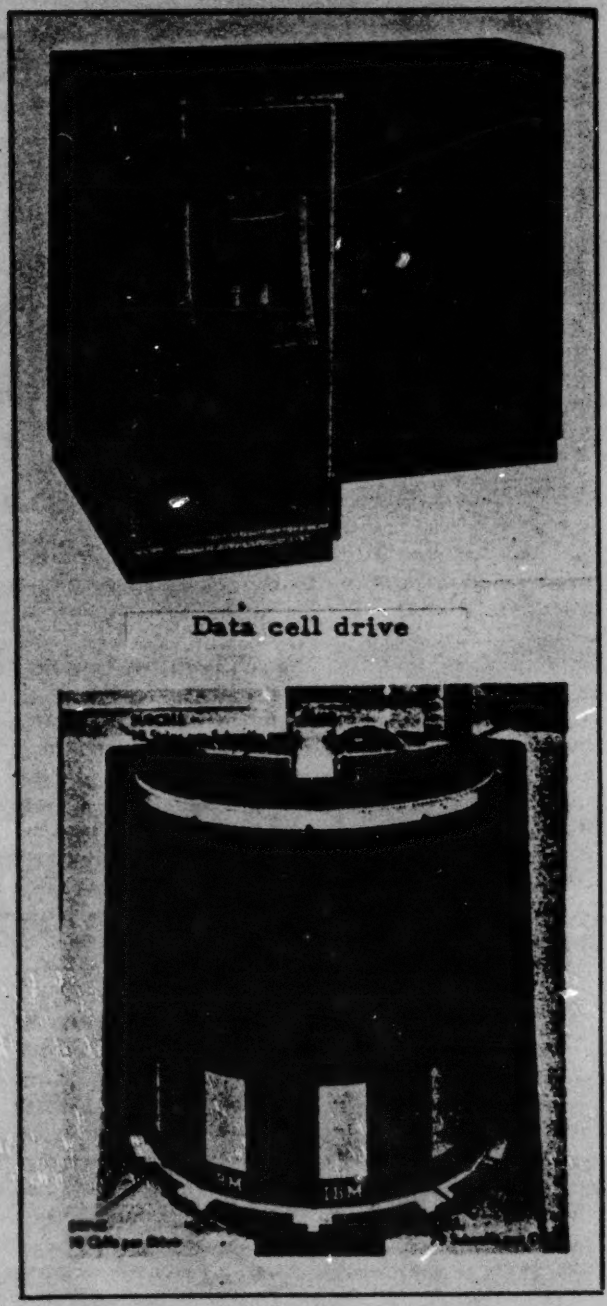


Figure 24. Data cell.

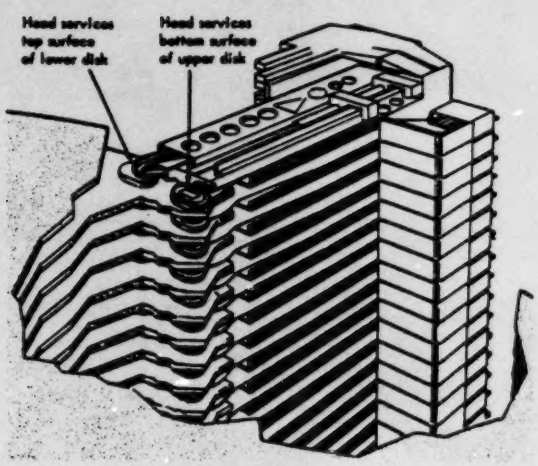
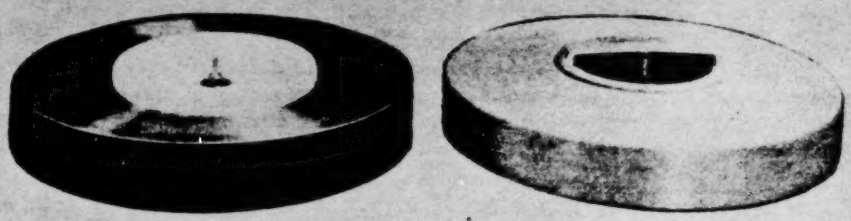


Figure 25. Magnetic disk storage.

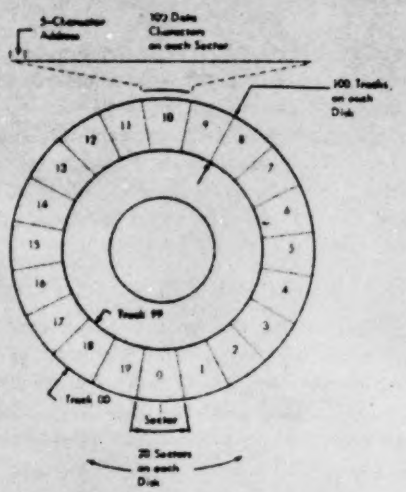
2. Large magnetic disk systems such as this one provide continuous direct access processing, real time transaction processing, a computer inquiry system that yields current information, and an unlimited program memory at low cost.

(b) Disk pack. While the principles of operations are virtually the same as for large magnetic disk units, the addressable bulk storage device using magnetic disk packs presents several new concepts. A disk pack provides the users of data processing systems with a fast, efficient, and low cost direct access device. It offers such features as high volume storage, fast data transfer rate, and rapid direct access to stored records. Disk packs vary in storage capacity. Storage capacity is determined by the number of disks in a pack and data storage arrangement. Disk packs come in 3-, 6-, or 11-disk units and store from 8 to 30 million alphanumeric characters per pack. The 6-disk pack is particularly useful in applications having intermittent high-low processing activity, and the file storage required is relatively small. The 11-disk pack is used where there is a large amount of processing activity with a large amount of file storage capacity. One magnetic disk pack device is called the disk storage drive.

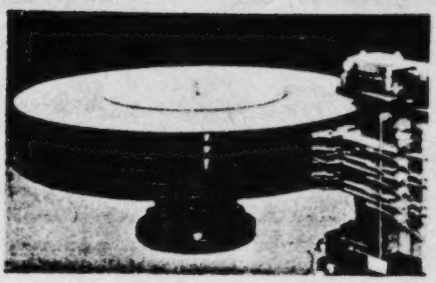
1. In the disk storage drive, information is stored on small magnetic disks (fig 26). Six of these disks are assembled into a lightweight, removable disk pack only 14 inches in diameter and 4 inches high. Although there are six disks, data is stored on only 10 of the 12 disk faces. The outer faces of the top and bottom disks are not used for storage. Between 2 and 7 million alphanumeric characters can be stored on these 10 disk faces. The storage capacity depends upon the model used. Since these disks are interchangeable, any number of disk packs can be used to store data. The number used is determined by the requirements of the user. By using removable disk packs, only those disk packs containing information needed for a particular application need be on the drives at the time the problem is being processed. The other disk packs containing information pertaining to other applications can be placed in their protective covers and stored. Changing a disk pack takes approximately 1 minute.



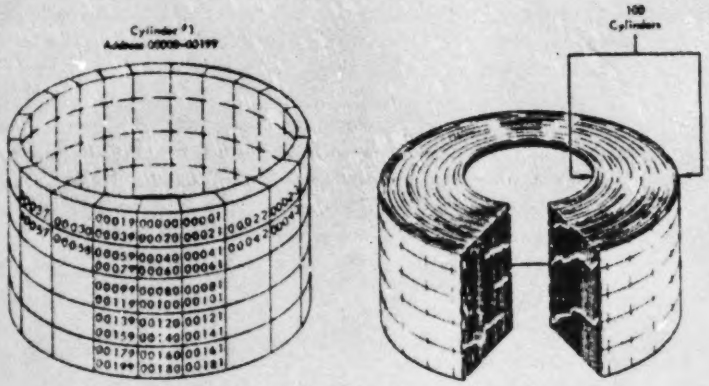
Disk Pack.



Disk Sector Organization.



Access Assembly.



Cylinder Concept.

Figure 26. Disk pack.

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2. Besides these advantages, disk packs allow the user to determine the number of disk drives needed for any particular application.

3. Information is read into or retrieved from storage by five access or selector arms arranged in comblike fashion on the access assembly (fig 26). Each access arm has two read-write heads. This arrangement of read-write heads and access arms eliminates the vertical up and down movement of the access assembly as found in some large magnetic disk devices. The access arms on the disk storage drive move only laterally, in unison, across the 10 disk faces. This makes all information located at the same position on all 10 disk faces available for reading or writing at the same time. By using a predetermined arrangement of input data that corresponds to the position of the access arms in conjunction with the direct-seek feature offered with this device, minimum access time can be obtained. Besides this unique sequential operating capability, the disk pack has addressable storage. Thus the user of a disk pack can use direct access and/or sequential processing in his computer applications.

4. Access time of the disk storage drive depends upon how the data is being processed; that is, sequentially or in direct access mode. The use of the comblike access arms and the 10 read-write heads greatly reduces the access time when the application is being processed in sequence. If the file is being processed in the direct access method, the average access time is 150 milliseconds. But this access time can be greatly reduced by using the direct-seek feature which this device offers. This direct-seek feature permits the access assembly to seek out elements of data without having to return to its home position. When the direct-seek feature is used, access time is considerably reduced—almost in half.

5. The 10 disk faces of a disk pack are divided into 100 tracks which resemble the grooves on a phonograph record. Each track is divided into 20 sectors (fig 26). Each sector can store 100 alphanumeric characters. There are 20,000 addressable storage sectors in each disk pack with a storage capacity of more than 2 million alphanumeric characters. The combination of the 10 disk faces in a parallel plane and the new access assembly permits a different storage arrangement.

6. The 10 read-write heads of the access assembly are all located in the same relative position on each of the disk faces at the same time. Data stored in a sector of these 10 tracks is available at approximately the same time. For this reason only one seek operation is needed for all 10 elements of data. This organization of data on these 10 disk surfaces can be compared to a cylinder with 10 tracks of data available for processing with a minimum of access time required for access to them. This type of disk storage arrangement is called the cylinder concept.

b. Nonaddressable bulk storage. Nonaddressable bulk storage devices usually are used to hold the voluminous master files used in sequential processing. Nonaddressable bulk storage devices are characterized by four things: first, their storage locations are nonaddressable; second, they have unlimited storage capacity; third, they are low in cost; and fourth, they are relatively slow. There are three nonaddressable bulk storage media: magnetic tape, punched cards, and punched paper tape.

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(1) Magnetic tape. Magnetic tape is an excellent example of nonaddressable bulk storage. It is a rapid method of output when used to create storage. It is a rapid method for re-entering the information into the system for use at a later time. It is possible to store 5 to 28 million characters of data on a single reel of tape. When compared with the number of characters which can be stored on drums or cores, this is a large volume. Magnetic tape allows files to be unlimited in size since any number of reels can be used. The ease of reading from or writing on magnetic tape without unusual conversion devices makes magnetic tape by far the least expensive form of storage per character of information stored. The advantages of magnetic tape are that it has fast reading and writing speed, requires a small storage space, can be used over and over again, and has the least cost per character recorded.

(2) Punched cards. Another device commonly used for nonaddressable bulk storage is punched cards. Again, the slower speed of reading and punching devices hampers the full application of punched cards within the computer system. But, because of lower cost for card input-output to the computer and other considerations such as ability to read the individual card, sorting, and other such factors, punched cards are quite popular as a method of bulk storage. Constant improvements are being made in machinery to read and punch these cards.

(a) There are several other things that should be noted about the use of punched cards for bulk storage. It is possible to manually process punched cards, although this is not true for the other nonaddressable bulk storage devices. They can be interpreted; they serve as source documents into a system; and they can be sorted inexpensively.

(b) There are several disadvantages in using punched cards as nonaddressable bulk storage. Their size and special handling requirements create problems in filing and storing the cards. The input or reading and punching devices operate at a relatively slow speed when compared to magnetic tape.

(3) Punched paper tape. Punched paper tape is currently used as a storage device in a number of computer systems. Some Army installations store transaction data on punched paper tape for input to the computer. However, certain disadvantages (such as slower speed of reading and punching and cost of conversion from punched paper tape) have restricted its use in the field of automatic data processing. The proper place of punched paper tape in automatic data processing will be determined by how well and how fast its disadvantages can be overcome. Let us examine the advantages and disadvantages of punched paper tape.

(a) Several advantages result from using punched paper tape. A reel of punched paper tape is inexpensive. It is possible to have variable record lengths. One of its most important advantages is that it can be created as a byproduct in preparing a hard-copy document. This leads to a more integrated data processing system.

(b) Generally speaking, there are four disadvantages in using punched paper tape for nonaddressable bulk storage. First, when it is prepared as a byproduct, it is not in sequence. If punched paper tape is used to hold the master records, sequencing of this data is very important. It is important to note that punched paper tape can be stored and placed into sequence. but it is such a slow input and output to the system that the cost of using it is very high. (When used as input in direct access processing using addressable bulk storage, it can be used efficiently since this type of processing requires no sequencing of data.) Second, punched paper tape requires a large filing area. Third, it requires greater care in handling. Fourth, the reading and punching speeds are slow when compared to magnetic tape and punched cards.

SECTION VII. INPUT–OUTPUT DEVICES

25. GENERAL. There are three major steps in every data processing task. This is true for both business and scientific applications. First, the data must be fed into the computer; second, it must be processed. Finally, the processed data must be written out of the computer. In the past, the middle state of this process—processing—has received the greatest amount of consideration in the development of a data processing system. At the present time, however, more and more stress is being placed on data preparation methods and on output presentations. Users of data processing equipment are becoming more discriminate in their choice of systems. The variety and merits of available input and output equipment are extremely important in the selection of a system. In fact, these input and output devices frequently are the most significant considerations in the purchase of the system. It is believed that in another 10 years, pereripheral equipment will account for 75 percent or more of the total hardware cost.

a. Terms. Input and output media and devices are an integral part of the peripheral equipment of any computer system. The term "media" refers to any physical substance upon which data is recorded and transmitted to and from the computer; e.g., punched cards. Input and output devices refer to the mechanical or electronic devices that enter data in a computer or record the processed data received from it.

b. Objective. The objective of this section is to consider the main media used for input and output, the importance of computer input, the factors of input effectiveness, and the principles of computer format. We shall also consider the methods and machines which we use to translate our language into machine language and to translate machine language into our language.

26. INPUT AND OUTPUT MEDIA. How can we talk to a machine? First, we must use a language that it understands. This language may consist of the presence or absence of holes punched in cards or paper tape, or the presence or absence of magnetized spots on tape. Information to be used with computer systems can also be in the form of direct access storage devices, magnetic ink characters, optically recognizable characters, microfilm, and display screen images, and communication network signals. Some of these devices are shown in figure 27.

a. Punched cards. From earlier instruction and from personal experience, we have become familiar with the rectangular punched card.

(1) Using punched cards to put data into the computer has several advantages. The cards can be handled, sorted, corrected, and manipulated manually, if necessary. If a computer is replacing electric accounting machine operations, card files and punched card equipment may already be available. Almost all medium size computers can accept punched cards as direct input. Finally, punched cards can be used as source documents or as records to meet legal requirements.

(2) There are also disadvantages to using punched cards. Erasing or correcting the data punched in the card is difficult, and each individual card can record only 80 or 90 characters. Because of the physical characteristics of the cards, files become bulky. In addition, an inventory of blank cards must be maintained.

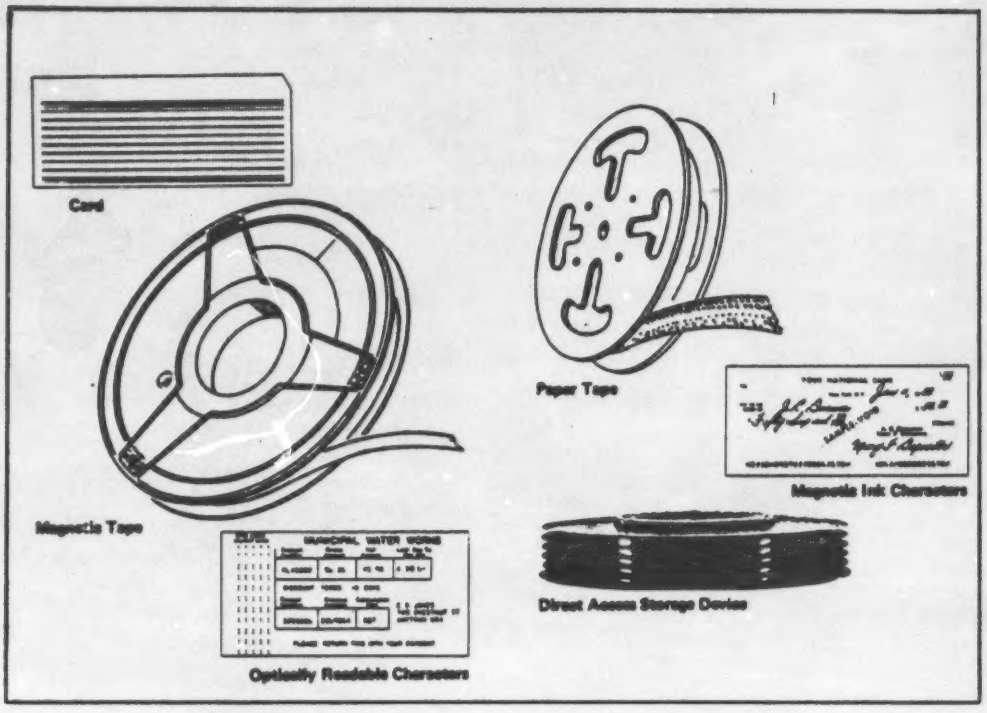

Figure 27. Input and output media.

b. Punched paper tape. Although less widely used today than punched cards in commercial automatic data processing systems (ADPS), paper tape seems to be gaining ground. This is largely because of the strong emphasis being placed on tape as a common language medium for communication among business machines of all types.

(1) Punched paper tape (fig 28) has columns similar to those on a punched card, but the number of columns is limited only by the length of the tape. It is frequently, but not always, produced as a byproduct of another operation. Punched paper tape can be classified according to the type of depression made in the tape (chad or fully perforated, which has holes punched in the tape; and chadless, which has depressions instead of holes). The basic classification of paper tape, however, is according to the number of channels on the tape (fig 29). The most commonly used tape sizes are five-channel tape and eight-channel tape.

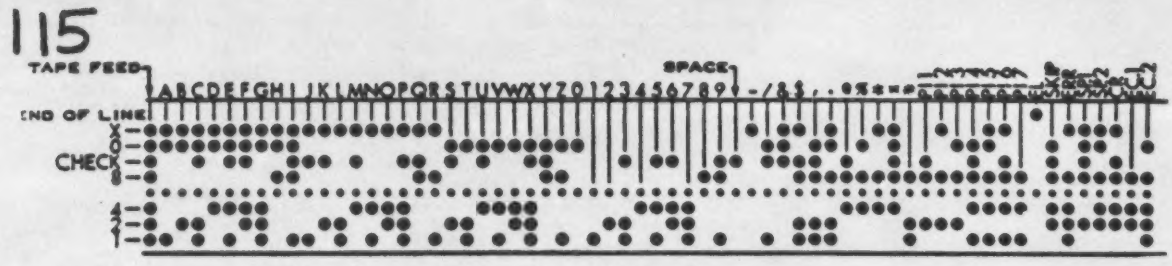

Figure 28. Punched paper tape.

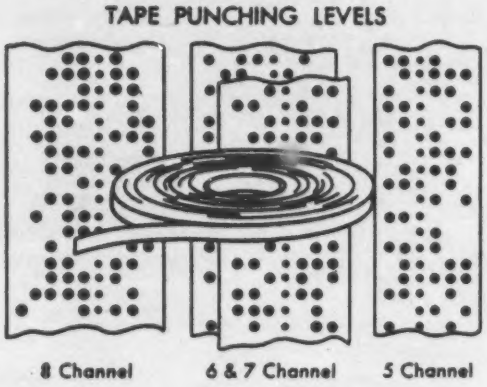

Figure 29. Classifications of paper tape.

(2) Teletype machines use a five-channel code for transmission. Each character must be represented in a five-bit code. (A bit in any channel is represented by a hole in that channel. A no bit is represented by the absence of a hole.) In this five-channel code only 32 different characters may be represented.

(3) In actual operation, we need 36 letters and numbers plus special characters. Therefore, it is necessary to make certain punch combinations do double duty as letters and figures by preceding them with a special shift punch to indicate whether we are reading letters or figures. A letter shift precedes a letter or a group of consecutive letters. A number shift precedes a number or group of consecutive numbers. The disadvantages of this coding system are that it holds a limited number of combinations and that there is no provision for checking accuracy.

(4) The six-channel code provides for uppercase and lowercase letters. This system is rarely used in computer input since there is no need for this type of differentiation.

(5) The seven-channel code structure consists of a six-channel code with a seventh channel as a check channel. This number of channels enables each character to be represented by an odd number of holes. If a character is represented by an odd number of holes in the six-channel code, no hole is added in the seventh channel, since there is already an odd number of holes. If a character is represented by an even number of holes in the six-channel code, a hole is added in the seventh or check channel. Since every character must be represented by an odd number of holes, any even-numbered combinations detected are interpreted as errors and cause an error indication to be made to the operator.

(6) An eight-channel code system is used on most computers. The eight-channel code is also used for controlling byproduct-producing equipment.

(7) Paper tape is inexpensive to buy and to use. It has a variable record length and is not limited to 80 or 90 columns. The different channel codes give paper tape a great amount of versatility, and its lighter weight makes it easier to mail than punched cards. There are certain disadvantages to punched paper tape, such as the difficulty of sorting it. Also, it is often awkward to file and handle. Paper tape tears easily and it is difficult to read with the eye. Moreover, it is difficult to reclassify information without first changing the data to some form of unit record, such as punched cards.

c. Magnetic tape. Magnetic tape (fig 30) is made from iron oxide which has been coated on plastic or other nonmagnetic substance. Unlike the punched holes of cards and paper tape, spots are magnetized on this tape to represent data. Magnetic tape can also be classified in two ways—according to the type of material and according to the number of channels. Magnetic tape is usually produced by the computer in the form of output, and it is the most efficient input or output medium for a computer.

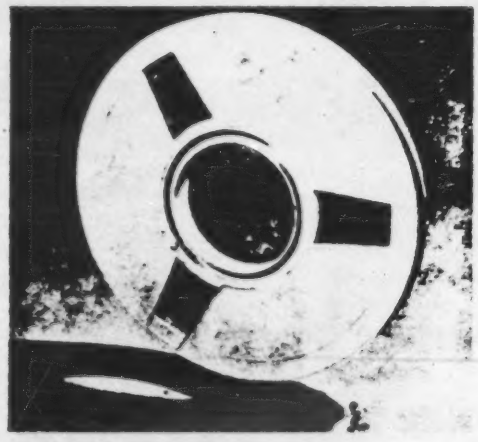

Figure 30. Reel of magnetic tape.

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(1) The first type of magnetic tape used in computers was the metallic tape. It was very thick, and because of this thickness the number of characters that could be placed on each reel was comparatively small. Later, acetate tape was developed as an improvement over the metallic tape since it was thinner and, consequently, more tape and records could be placed on one reel. Almost all metallic and acetate tapes have been replaced by various improved magnetic tapes. There are many brands of magnetic tape which vary in width and storing density.

(2) Magnetic tape, like paper tape, is also classified by the number of channels it has. However, a check channel is always used in magnetic tape. For instance, some computers use a seven-channel code, and others use a nine-channel code. The seventh and ninth channels are used for the parity check.

(3) Regardless of the type of material or code used, magnetic tape has many important advantages over the other input and output media. It is the fastest medium; it is reusable; and it requires a relatively small storage space for a large number of records.

(4) The use of magnetic tape as a computer input or output medium has one major disadvantage. Data recorded on tape cannot be read manually. Therefore, data conversion devices are sometimes necessary prior to tape input and following output from the computer.

d. Volume of input and output. So far, we have considered main volume input media—punched cards, punched paper tape, and magnetic tape. Manual input and output through the use of the console or console typewriter are occasionally considered as another medium, but this is seldom used in operations of appreciable volume and will be explained later when we discuss input and output devices.

e. Volume output media. The main volume output media are the same as those used for input—punched cards, punched paper tape, magnetic tape, and, PRINTING. We can best explain printing by considering printers. Since printers are output devices, we will describe them later when we discuss output devices. The most important facts to remember concerning input and output media are that the three main volume input media are punched cards, punched paper tape, and magnetic tape; the four main volume output media are punched cards, magnetic tape, punched paper tape, and printing.

27. IMPORTANCE OF COMPUTER INPUT. We cannot overemphasize the importance of computer input. Consider the following reasons for this importance: the extent and nature of the processing action required of the computer is determined by the content of the input data in relation to the content of the output data. The collection and preparation of input data (from the time of its availability on the source document to the time the data is in form for machine processing) greatly influence the overall profits of a computer operation. The collection and preparation of input data usually have a greater influence on the overall speed of data processing than the speed of the computer itself. The accuracy of the input data, other factors being equal, determines the accuracy of the output.

28. FACTORS OF INPUT EFFECTIVENESS. It is necessary that we realize the importance of computer input and that we have a knowledge of some factors that will help us increase input effectiveness. Input data must be translated into computer language before the computer can accept and understand the data. If possible, the computer language should be created as a byproduct of the production of the source documents. The source document must be designed so that it is readily adaptable to permanent storage, and so that the data on the form is in the same format as that used for entry into the computer. This allows a machine language record to be prepared as a byproduct of preparing the document itself.

a. Equipment selection. Errors in input data must be eliminated to minimize run time on the computer. Effective input data can be produced by using the following equipment:

(1) Verifiers may double the effort and cost of the operation, but they will improve the quality of the input.

(2) Equipment that will produce a source document while creating a machine language record as a byproduct will facilitate visual verification.

(3) Input equipment with built-in self checks will also help to reduce errors.

b. Procedures. Effective input data can be produced by using the following procedures:

(1) Redundancy checks. Adding a digit or two to frequently occurring identification numbers such as account or stock numbers.

(2) Comparison checks. Preparing the input twice then comparing the two inputs.

(3) Early preparation of the machine language record. Because of the timelag between a transaction and the computer's need for the data from this transaction, it is best to produce a machine language record either concurrently with or immediately after the transaction. A delay in this regard frequently results in forgetting to record the transaction or in recording only part of it.

(4) Batching of input data. For some computer applications, input should be batched or accumulated. The batched records are then processed all at one time. This method has proved to be an effective way of saving money and time in machine changeovers. For those applications which call for the monthly information to be processed on the last day of the month, much of this monthly data can be cut off at another time during the month without impairing its usefulness. Through these means, the computer can be used on a more even or uniform basis.

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(5) Reduction of human errors. Most of the errors in input data are caused by people. Steps must be taken to reduce these errors. First, and perhaps most important, we must select personnel for computer input preparation who are least likely to make errors. Further, as suggested earlier, human errors can be minimized by eliminating the delay caused by converting source documents to computer language. Specifically, this can be done if the computer language is produced as a byproduct of document preparation. There are four common classes of errors caused by people: recording the wrong information in the right place and in the right manner (e. g., transposing two digits of a number); recording the right information in the wrong place but in the right manner (e. g., punching a punched card in the wrong fields); recording the right information in the right place but in the wrong manner (e. g., writing source documents in an illegible manner); and failing to record information completely (omissions).

(6) Reducing the amount of data and data handling. Since any conversion of form increases opportunities for errors, it is best to transmit input information directly into machine language. Also, computer efficiency is generally improved by using the least possible amount of input, since the preparation of input data is expensive. (The data content and the form of the desired output determine the amount of input required.)

29. DIRECT CREATION OF INPUT DATA. Source data in the form of typewritten or written information can be translated by a manual operation to the desired machine-processable medium (punched card, punched paper tape, or magnetic tape). However, manual conversion is slow and the error rate is so high that duplicate operations are often used to detect mistakes. These manual operations reduce data to various media, and they can be classified according to the medium produced.

a. Punched card. Manual card punching is a common way to get data into machine-processable form.

(1) Keypunch. When one key on a keypunch is struck, one or more holes are created in a punched card to represent one character. The original data and punched cards are then given to a second operator for verification.

(2) Verifiers. Verifying equipment senses holes but does not punch. The verifying operator, reading from the original data, strikes the same keys as the first operator. If he punches a key which differs from the holes punched in the card for a particular column, the keyboard locks. The operator then depresses the error reset key and again attempts to punch this information. If it is still in error, the operator attempts to punch this information once more. If an error is indicated a third time, the machine notches the card over the column in error and advances to the next column. If the entire card is verified and found free of error, a notch is made at the 80-edge to show that the data on the card is clean. If there is an error in any column of the card, the 80-edge is not notched. After the entire block of cards has been verified, all cards that do not have a notch in the 80-edge are removed and returned to the key-punch operator for repunching. The 90-column card system of verifying is done on the keypunch. A special switch is set to offset the punch dies so that the holes previously punched are elongated. An automatic verifier with oval reading rods reads these cards and rejects all cards with nonelongated holes in them.

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b. Punched paper tape. Electric typewriters convert source data to punched paper tape. Through manual keyboard operation these electric typewriters produce punched paper tape and readable record or hard copy at the same time. Direct creation of paper tape is possible if the hard copy produced is used only for verification. If the hard copy is a regular form which becomes a record, the paper tape is created through a byproduct operation. This byproduct operation will be explained later in this instruction.

c. Magnetic tape. Various devices have been invented which use a manually operated keyboard for preparing magnetic tape directly from source data. Only recently was such direct encoding of source data proved practical. Automatic data processing (ADP) installations are changing over, but many still use transcription facilities prior to tape input in order to use this input medium effectively. One of the devices for preparing magnetic tape directly is the Mohawk keyed data recorder, which uses a 47-character keyboard to record data directly from source documents onto magnetic tape. By setting a special switch, it can also be used to verify the recorded data. Data are recorded on magnetic tape by a read-write head. As the magnetic tape passes under this read-write head, it falls into a takeup bin which holds about 1,200 feet of 1/2-inch tape. Records are manually recorded on a 7-track format using a fixed record length of 80 characters. Other record lengths are available. National Cash Register has developed a family of devices for recording source data directly on magnetic tape.

30. BYPRODUCT CREATION OF INPUT DATA. To overcome the slowness and high error rate of direct manual conversion, a new method of converting human language to machine language was sought. As a result, we have seen the introduction of many types of office machines, such as the desk calculator; the bookkeeping, addressing, and posting machines; and the cash register. None of these machines was able to communicate with a data processing machine until the early 1950's. At that time, through the adaption of these office machines to punch or to read paper tape as a byproduct of their regular operations, this communication was made possible. Most of these machines now understand the five-unit telegraph code or common language tape because they use the same five-unit code that is used by standard printing telegraph machines. When one of these machines produce a six-, seven-, or eight-unit (or more) code tape or a magnetic tape, it is called a native language machine. This because it is understood only by another machine that uses a tape with the same unit code or number of channels.

a. Integrated data processing. Although various types of punched cards may be used in integrated data processing, it primarily refers to use of paper tape producing and actuated equipment for data handling in offices. The basic principles of integrated data processing are:

(1) At the point of origin, data is stored in punched paper tape as a by-product of typing the source document.

(2) This punched tape is then used to control other office machines to make the data self-perpetuating.

b. Edge-punched cards. Integrated data processing is concerned primarily with paper tape. However, it also includes punched cards in the form of the edge-punched card. One edge of this punched card is punched with a paper tape code. This can be done as a by-product of manual typing, or the coding can be produced automatically from previously punched tape or edge-punched cards. Edge-punched cards can be read to control other machines for the preparation of documents. These cards are standardized, unit-type records which permit easy identification, filing, and handling.

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c. Sample integrated data processing application. The Friden flexowriter (fig 31) is a type of integrated data processing machine. It is an electric typewriter with a built-in device that will punch paper tape (and, in some instances, punched cards) as a byproduct of typing hard copy. It will also read tape and produce printed copy. The Friden flexowriter, which produces a five-position-code tape, can be used to type an internal company order from the salesman's handwritten order or from the customer's typed order. From a master customer file, the typist takes a strip of paper tape or an edge-punched card that contains a five-position code record of standard customer information, such as name, address, and shipping instructions. This piece of punched paper is fed into the reader of the Friden flexowriter, which activates the automatic typing of this information on the order. The typist then copies in the variable information, such as the date and number of the customer's order and the description and quantity of material ordered. When the typing of the order is completed, the work is verified. Since a large part of the typing of standard customer information has been done automatically at high speed, it is unnecessary to verify this part, which is usually confined to a colored or shaded area on the order form. Thus, the speed with which the order is typed is increased and there is less chance of undetected human error. As a by-product of this typing, a new five-unit code paper tape is produced by the machine. This tape can be used for input to the computer or for processing on any tape reading machine.

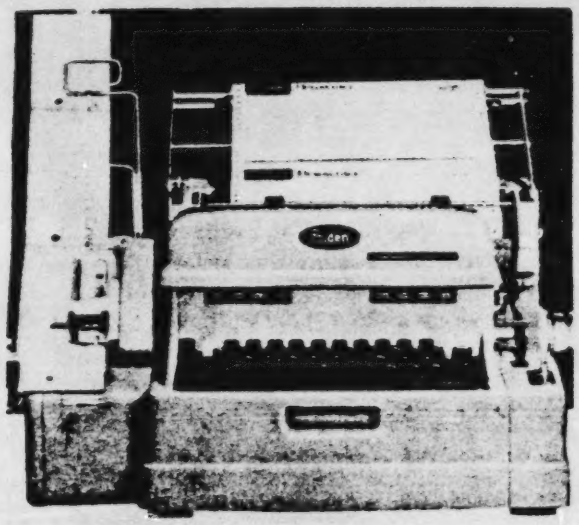

Figure 31. Friden flexowriter.

d. Punched card and paper tape byproduct devices. As an outgrowth of the integrated data processing concept, many devices have been developed that will produce either a punched paper tape or a punched card as a byproduct of the creation of the source document. Some of these devices have the paper tape punch or card punch as an integral part of the device. Others have a black box connected to the device which enables the machine to punch paper tape or cards. Punched paper tape is the most frequently used type of byproduct input data.

31. ADVANCE PREPARATION OF INPUT DATA. So far we have described input methods that are based on the assumption that data was on typed or written documents. These methods are expensive and may be inaccurate. An improvement on this means is found in the advance preparation of input data with the output from one stage serving as input at the next stage. One example of this method is the punched card bill prepared and distributed to bill a customer. Cashiers get a customer's bill to identify collection. A collected bill card is used as data input for crediting a customer's account. Consequently, manual conversion of input data is eliminated in routine cases. Advance preparation of data can be widely used within an organization since there is almost complete freedom over media used internally. Further, mass preparation of data at one stage can minimize manual conversion at the next stage.

a. Tag readers. Inventory control is facilitated by mass producing punched cards or other machine media at the time of purchase or manufacture. Special devices print and punch tags with item name, number, size, manufacturer, and other desired information when the inventory is received. When an item is used or sold, one part of the tag is detached. A machine reads each tag and punches a card for further processing. The tag originally attached to the item may be suitable for further processing without conversion. Many manufacturers produce equipment for this process.

b. Transaction recorders. Detached sections of inventory tags may be placed in a transaction recorder that serves as a cash register at the point of sale. The recorder automatically reads holes in the tag and produces a continuous punched tape. The variable data is recorded manually on a keyboard. Another type of transaction recorder in the form of a factory production recorder is used to punch cards with start-stop time and numbers for workers, jobs, and machines.

c. Magnetic ink character readers (MICR). One of the more recent developments in the field of advanced preparation of input media actually reads characters printed on original paper documents. Stanford Research Institute designed the first magnetic ink character recognition reader for sorting and accounting for paper checks (fig 32). Since then, other companies have also developed data processing systems for handling checks preprinted with magnetizable ink. Generally speaking, these systems use the following procedures: Before issuing checks to a depositor, a bank prints its identification number and the depositor's account number on each check. The characters are printed with a special ink that will conduct an electrical impulse. These inks usually contain ferrites such as those used in magnetic tapes. After a customer writes a check, the first bank handling it is supposed to imprint the amount of the check in a similar way. Then, the ink can be read magnetically by machines as well as visually by people. The checks are then processed by the MICR reader which acts as a high speed sorter. MICR reading heads produce electrical signals when the ink passes beneath them. Wired recognition circuits analyze the signals and compare them with stored truth tables to determine which recognizable character has been sensed. The greatest problem seems to lie in the magnetic ink process. Imperfect printing and previously damaged documents cause fairly high rejection rates and cause clerical processing of the rejected material. The MICR process has two interesting features. First, the characters can be read by both people and machines. Second, and most important, it is the first significant application of machine-processable documents to gain acceptance throughout a large industry.

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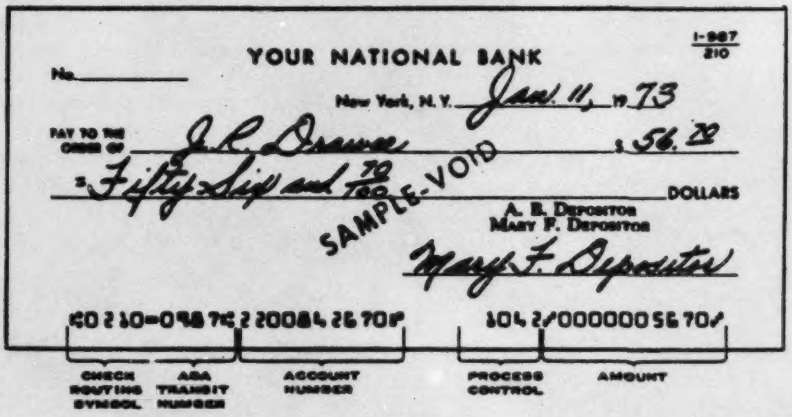

Figure 32. MICR check.

d. Optical scanning readers. Optical scanning readers are among the newer devices on the market. They offer the most potential for general usage as input devices in the future. Because these readers permit the direct input of normal printed material into the computer, they promise to reduce the bottleneck of manual keystroke operations and verification of computer input data. The basic function of optical scanning is to read data from printed documents, translate each individual character into suitable code, and either transmit the coded information directly to a computer or transcribe it onto punched cards, paper tape, or magnetic tape.

(1) Several different scanning methods have been introduced, but the predominant technique is stroke analysis. The document is flooded with light and the characters are reflected through a system of lenses and tubes. The character is converted to a pattern of electrical signals which are received by a special unit that employs a recognition program. Working from a stored truth table, the device decides whether or not the particular combination of strokes constitutes a recognizable character.

(2) Existing optical scanners handle a variety of source documents, including cash register tapes and paper documents up to 10 by 14 inches in size. Some readers can read only one line at a time, while others can read several lines or a page at a time. Advertised reading speeds range from a hundred to several thousand characters per second or from a hundred to a few thousand documents per minute.

(3) One of the problems in this process is that printed documents vary in quality of printing and size of alphanumeric type. The solution to the problem seems to lie in the development of a single printing standard for quality of documents and size of type.

32. PREPARATION OF INPUT DATA AT REMOTE LOCATIONS. As mentioned before, it is most desirable to translate or convert data into machine language as soon as possible—preferably right at its source. Therefore, a device is needed to record original data in machine language form at points remote from the tabulating or processing center, such as branch offices and warehouses, stockrooms, shipping platforms, and even vehicles. This device must be portable and not require a specially trained operator. Ideally, the cards, when forwarded from the field, should be ready for immediate processing. Thus far, several devices have been developed to meet these needs.

a. Mark-sense cards. This specially designed card (fig 33) records information by means of marks made on the card with a special electrographic pencil. A horizontal or slightly slanted pencil mark is made on the card. The position of the mark with respect to the top of the card indicates the numerical value of the data. The card is then passed through a mark-sense reproducer. This device uses three brushes to make an electrical contact with each mark. The impulse created causes a punching mechanism to punch a hole in the card in the same relative position as the mark.

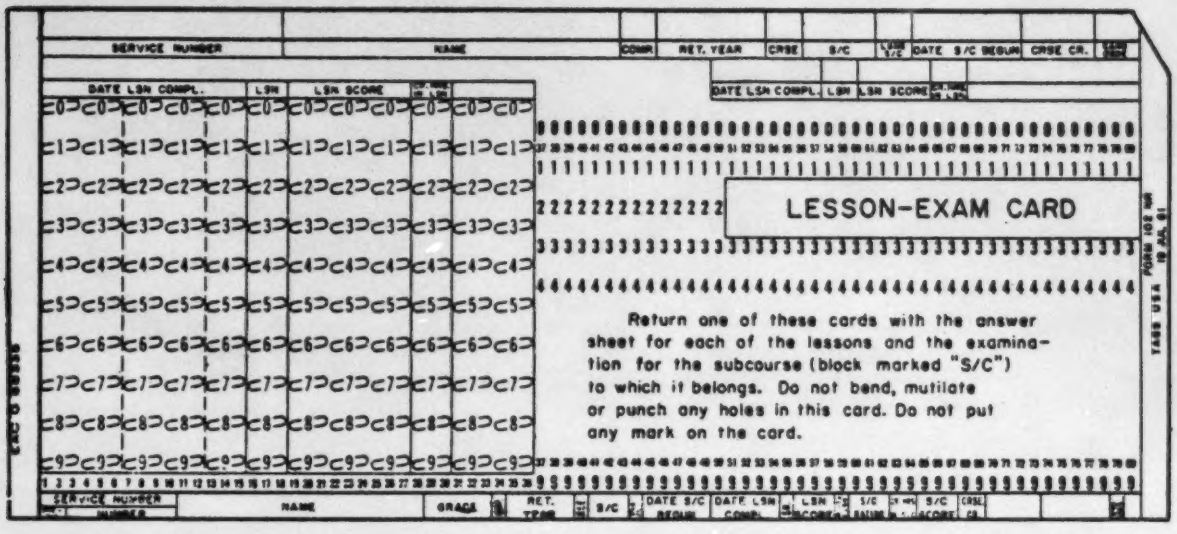
LESSON-EXAM CARD
Return one of these cards with the answer sheet for each of the lessons and the examination for the subcourse (block marked "S/C") to which it belongs. Do not bend, mutilate or punch any holes in this card. Do not put any mark on the card.

Figure 33. Mark-sense card.

b. Prescored cards. Another portable device that can be used to record data in machine language is the port-a-punch (fig 34). The process of recording information with a port-a-punch is called penching. A card with a prescored rectangle around each number to permit uniform holes is placed on a penching board. A template, designed to hold the card in place and guide the user in making holes in the desired locations on the card, is placed over the card form. (Occasionally, a thin sponge is used for the same purpose.) A penching tool is then pressed down vertically through the template, forcing out the prescored area. Because of the problem of scoring the cards too closely from column to column, only every other column is scored. Consequently, each port-a-punch card has only 40 columns.

Figure 34. Port-a-punch.

c. Data punch. Another device used in the creation of punched card data at a remote location is the data punch. In using this device, a punched card is placed in it and the desired information is placed on dials. One model of the data punch allows only six columns to be punched at the same time. This means that only six characters of data can be entered at the same time. There are other models of this device which are currently available.

33. MAIN VOLUME INPUT AND OUTPUT DEVICES. Thus far we have considered pre-input devices used for preparing and converting the data into a machine-processable medium. At a later stage, and perhaps after a conversion operation, data are introduced into the computer. An input device is the mechanical unit designed to bring data to be processed into the computer. Main volume input and output devices are connected to the computer for direct read-in. Selection of a device depends on record length, equipment speed, and the permissible processing time.

a. Punched card input devices. There are two types of punched card input devices. These are mechanical readers and optical readers.

(1) Mechanical readers. Depending upon the system used, mechanical readers may be modified electric accounting machines such as the collator or the reproducer. As the card passes through the machine, pins or brushes over each column read the holes in the card by making charged contact through the holes. An electrical impulse, which is automatically converted from punched card language to computer language, is then transmitted to the computer.

(2) Optical readers. In optical card readers, a card passes between a photoelectric cell and a beam of light. There is one photoelectric cell for each punching position. As the beam of light shines through the holes in the card, it activates the photoelectric cell. When this happens, an impulse is transmitted to the computer. As might be expected, optical card readers are much faster than mechanical card readers.

b. Card read/punch. The card read/punch combines a card reader and a punch in a single unit. The IBM 1402 card read/punch (fig 35) has a file feed on the reader which allows several thousand cards to be loaded at a time, and both the reader and the punch can be loaded and unloaded while the machine is running. This device has five stackers, each having a capacity of 1,000 cards. Cards from each feed can be program directed to three of the five pockets. The center pocket can receive cards from either feed. This stacker feature has the advantage of identifying exception or error cards through programing during the reading and punching operations.

c. Punched card output devices (card punches). Card punches are mechanical output devices that convert impulses from the computer to punched card language. The impulses transmitted from the computer activate the dies that punch the holes in the card. However, the mechanical features of card punches make them a slow form of output.

d. Paper tape input devices. Paper tape readers can also be mechanical or optical.

(1) Mechanical readers. An example of a mechanical tape reader is the Friden flexowriter. The holes in paper tape are read by means of pins or brushes over each channel, similar to mechanical card readers. A charged contact is made and an impulse is transmitted to the computer. Thus, the paper tape language is automatically converted to computer language.

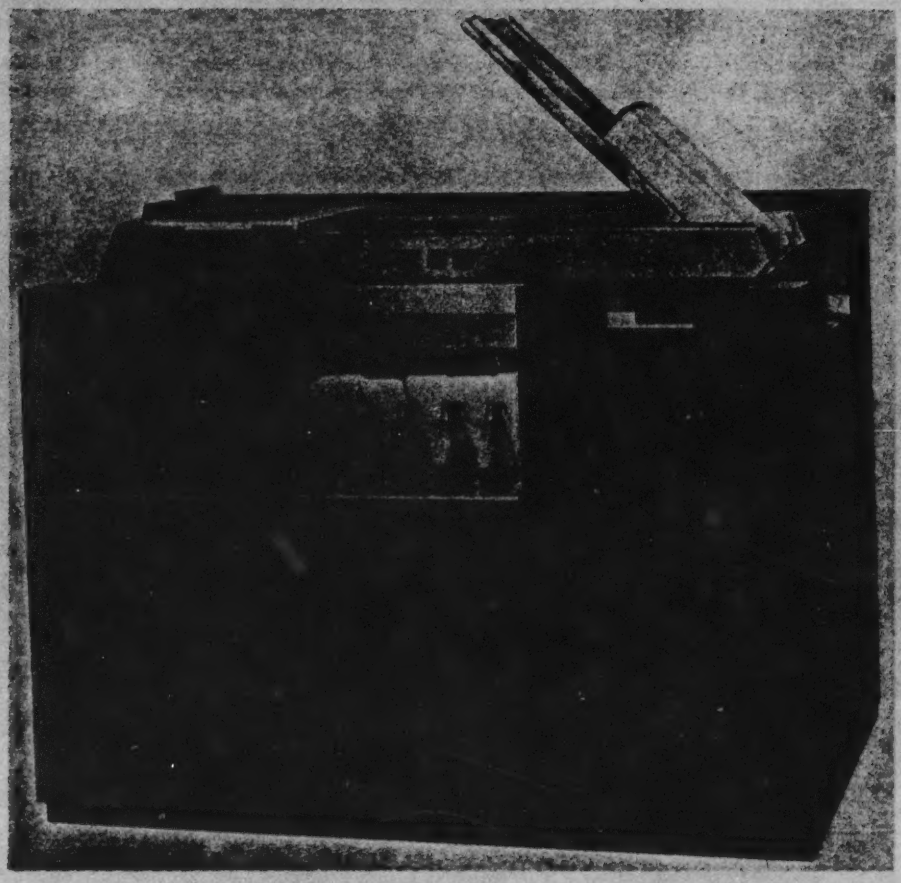

Figure 35. IBM 1402 card read/punch.

(2) Optical tape readers. In using an optical tape reader (fig 36), a beam of light shines through the holes in the punched paper tape activating photoelectric cells located beneath each channel. An impulse, automatically converted from tape language to computer language, is transmitted to the computer. As in the case of punched card readers, the optical reader is much faster than the mechanical reader.

e. Paper tape output devices—paper tape punches. Paper tape punches are mechanical output devices that are very similar to card punches except that tape codes are punched instead of card codes. Like card punches, tape punches are a slow means of output.

f. Magnetic tape devices. Each system that is capable of using magnetic tape as input or output will have tape units (fig 37) to handle the reading of the magnetic tape. These units may be called tape units, tape handlers, UNISERVOS, or data readers.

(1) Method of reading and writing. The typical tape unit has two tape reels: one contains the magnetic tape and the other is a takeup reel for the tape that has been read (fig 37). To transport the tape from one reel to another, the tape unit uses a series of guide rolls. Also, in the tape unit, are a read-write head, erase head, and photoelectric cell. Before passing the read-write head, the tape takes a big dip. The purpose of this slack is to keep the tension off the tape during the sudden burst of speed generated by a read

or write instruction from the computer. This electromagnetic read-write head reads tape by translating magnetic spots to electrical impulses that are sent to the computer. It writes tape by translating electrical impulses from the computer to magnetic spots on the tape. The photoelectric cell recognizes the end of the tape which is designated by a tape mark. The tape is mounted on the tape unit much the same as movie film is mounted on a projector.

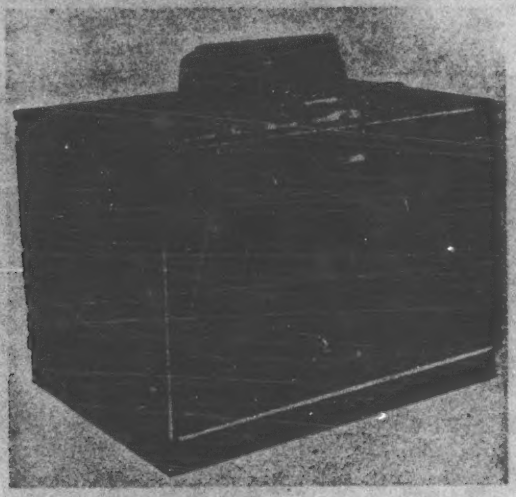

Figure 36. Optical tape reader.

Figure 37. Magnetic tape unit.

(2) Interrecord gap (fig 38). On most magnetic tape it is necessary to have a space between records. This space is required because of the speed at which the tape is read and written and also because there is no mechanical sprocket to facilitate acceleration and deceleration. When the machine writes a record, the tape units accelerate to a very high speed. It takes a fraction of a second to attain that speed. Similarly, it takes a fraction of a second to bring the tape to a standstill after the information has been written. Consequently, some amount of blank tape exists between blocks of information. This space is known as an interrecord gap. Attempts have been made to eliminate this gap.

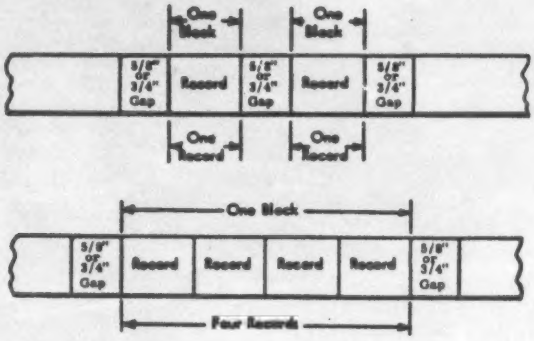

Figure 38. Interrecord gaps.

(a) A recently developed tape unit uses a method of writing while the tape is rewinding. When a tape is being written on, the computer alternates writing and skipping until the entire tape is used. The interrecord gap is then equal to the record length. At this point it reverses, writing in the gaps left by the first writing and skipping over the already written portions.

(b) Some systems require that each record be designated by a beginning and end of record mark. As soon as the end of record mark is sensed, the tape unit automatically repositions or backspaces so that when the next read instruction is received the tape unit will reach the proper speed by the time the beginning of the record mark is sensed.

g. Graph-plotter. A mechanical device called a graph-plotter is connected to the computer and translates impulses from the computer to the movement of an arm holding a mechanical pen. The pen either puts dots on a sheet of paper or draws lines. The paper can be either single pages or a continuous form. This graph-plotter enables graphic representation of data as output from the computer.

h. Printers. Hard copy is a necessity in any business data processing system. As the computer was used more and more to solve business problems, the amount of output increased greatly. This amount of output caused the need for faster printing devices. As a result, high speed line printers now provide the primary means of making data available for examination by man after it has been processed by the computer. High speed printers are divided into two classes: impact printers and nonimpact printers.

(1) Impact printers. The impact printer prints by means of a mechanically driven type bar on a wheel which is pressed against paper and ribbon. The majority of printers in use at ADP installations today are impact printers. There are many different types of impact printers in use. Most of these are classified as on the fly printers. This type of printer has a print wheel or chain which rotates continuously, and a lightweight, fast action hammer that presses the paper against the wheel or chain at the exact moment the required character is in position. This action gives the printer a much faster speed. Let us examine some of these type printers.

(a) Type bar printer. Alphabetic, numeric, and special characters are located on a single type bar which moves horizontally across the paper. The bar is made so that each different character successively passes each print position. Printing takes place when the character to be printed corresponds with the character read from print storage. Printing speed depends on the number of characters being used in the set.

(b) Chain printer. This type of printer has the printing characters assembled on a chain (fig 39). This chain moves horizontally across the paper. Each character is printed as it is positioned opposite a magnetically actuated hammer. This hammer presses the paper against one piece of type in the moving chain.

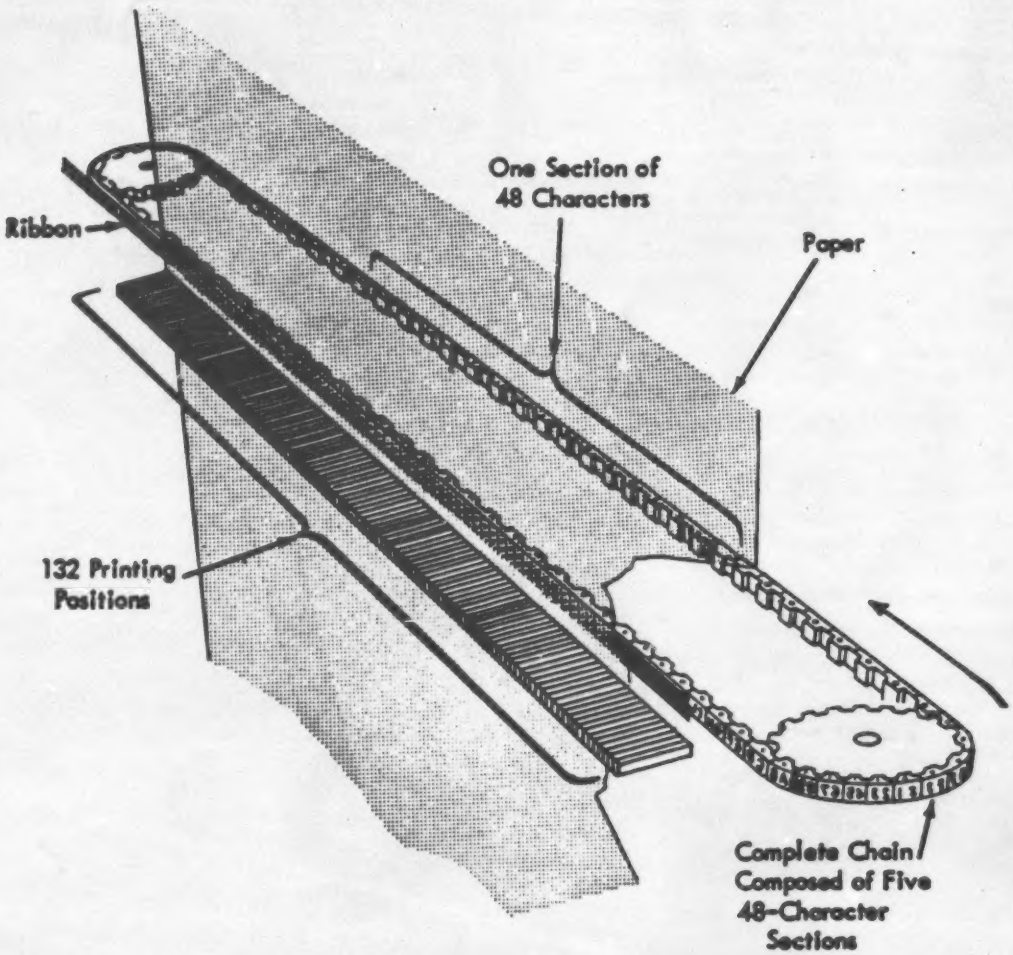

Figure 39. Chain printer.

(c) Drum printer. On this type of printer, printing characters appear on a print drum which rotates at high speed. Only one character appears across one row of the drum. As the character approaches the printing position, print hammers strike the paper causing the character to print.

(2) Nonimpact printers. Nonimpact printers capable of printing thousands of lines per minute have been developed. These units incorporate a variety of electrical and chemical processes to print character images on paper. The demand for printers that are better able to keep pace with the data handling rates of modern computers probably will result in improvements in the nonimpact printers and a pronounced shift in emphasis to nonimpact printing techniques. However, nonimpact printers cannot produce simultaneous multiple copies nor can they produce printed documents of sufficiently high quality for use as routine business documents. The nonimpact printer is different from other mechanical printers in that no type slug or face is used. Some nonimpact devices use a matrix of wires at each printing position to form a character. For example, to print an E, the wires that form this letter are pushed out slightly by means of a push rod or hammer. They strike the ribbon against the page, thereby printing the letter. Although a solid line of print does not result, it is legible enough for most practical purposes. There are two types of matrix printers: simultaneous and scanning.

(a) The simultaneous printer. This type printer pushes all wires necessary to form one letter at once.

(b) The scanning matrix printer. This type uses rows of wires. Some of these scanning matrix printers use only one row of wires, and repeated impressions from this single row of wires form various characters. A five-wire row at each printing position, with the paper moving vertically, can print characters across the paper. A seven-wire row can be used for each line of print.

i. Soft copy Output in the form of printed documents produced by printers is frequently referred to as hard copy. Output of an impermanent nature, which usually takes the form of a spoken message or a message displayed on a visual display tube, is known as soft copy. Soft copy has been greatly improved in recent years. The big advantage of soft copy is the speed with which it may be transmitted from the computer's central processing unit to these output devices. The practicality of such devices is based upon the need to recover and use a large amount of information in a short period of time.

(1) Audio response units. In these devices, limited words and phrases are recorded on a fast access device. In answering an inquiry, a computer will develop the answer in the form of a series of digital code numbers. The audio response unit uses these code numbers to retrieve the designated words and phrases in the sequence set by the computer. The words and phrases then form the message.

(a) This method of answering inquiries is currently being used by the New York and American Stock Exchanges for the automatic handling of thousands of subscriber telephone inquiries about the current market prices on specific stocks. The subscriber dials the Exchange service and then enters a four-digit number to identify the stock for which he desires information. The computer uses this number to look up information on the desired stock and then sends this information to an audio response unit. This unit, in turn, converts the message into audio form by looking up prerecorded words. It then sends the message back to the subscriber over the telephone line.

(b) The user of such audio response units must take notes of the information he hears since the receiving units do not provide for the storage of such information. These systems are limited to answering inquiries and may have only limited potential for the Army's command control systems.

(2) Visual display output. A system which offers more potential to the Army is the visual display output (fig 40). These devices have been developed largely in connection with such applications as military command and control systems to direct and control a tactical operation and to control air traffic. In these applications, the commanders and controllers must keep abreast of the rapidly changing conditions and must analyze individual events in the perspective of a much broader total picture.

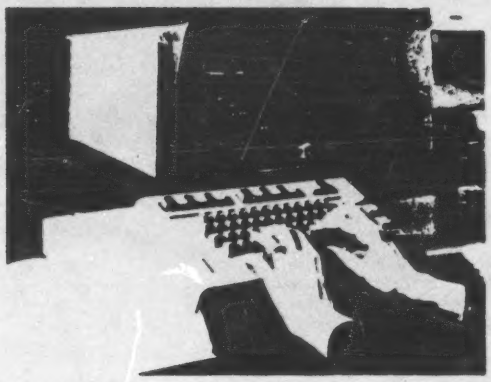

Figure 40. Visual display output.

(a) The heart of the visual display output system is the cathode-ray tube (CRT) on which data and charts are displayed. The data is called for by the operator from the console of the display device, and the electrical impulses are converted to display information on the face of the tube. The amount of information available depends upon the system and the tube size.

(b) The importance of this device lies in the fact that information may be retrieved almost instantaneously. The operator does not have to wait for reports and records to be produced on the printer. Hence, preparation time is greatly reduced.

(c) The use of display devices in command control systems, as well as for business applications, can be expected to increase in the future as volume production makes the cost more feasible. Much research still remains to be done in the areas of hardware development and programing. However, a sufficient amount already has been done to indicate a very promising future for computer controlled visual display.

34. SYSTEMS BALANCE. The computer can accept and record data in storage much faster than the input units can read it and much faster than the output units can write it. This problem of the incompatibility of speeds between the computer and its peripheral equipment results in a very inefficient use of the computer. When we consider the daily rental cost for a medium-size computer, we realize the significance of this inefficiency. The effective use of the central processing unit and the peripheral equipment is called systems balance. The following have been used effectively in achieving systems balance.

a. Buffers. A buffer is simply a storage device used to compensate for a difference in the rate of data flow, or time of occurrence of events, when transmitting data from one device to another.

b. Data channels. Although expensive, a data channel is used to allow an input or output that finishes its job to interrupt the main program and ask for further instructions.

c. Offline operations. Offline operations refer to those operations which are performed on devices which do not operate under direct control of the central processing unit.

d. Multiprograming. Multiprograming is simply a method which allows a computer to perform the simultaneous execution of two or more programs.

35. FORMAT CONTROL. Before proceeding with an explanation of format control, we must be familiar with the following terms used in organizing business data: any letter or numeral is called a character; characters may be grouped into words of data; one or more characters or words of data make up a field; related fields are grouped into records; related records make up a file.

a. Sequence. In processing data, a certain sequence is necessary to permit the computer to manipulate the data and to permit the user to obtain output in the form desired. Characters, words, fields, or records on punched cards, paper tape, magnetic tape, or printed records usually have to be arranged to fit different applications or processes.

b. Rearranging data. How can this data be rearranged? Input and output devices in conjunction with the computer have the ability to control the format of data or, in other words, to edit the data.

(1) Punched card. Punched card readers have wired plugboard panels for edit operations. Contents of the columns can be omitted and column sequence can be altered. In some of the older computers, card punches also use plugboards to control data edit operations during read-out and punch operations; however, in the modern computers, this operation is performed by a more sophisticated program.

(2) Paper tape. Computer programing is commonly used to edit data from paper tape readers and tape punches. However, both tape readers and punches may perform limited edit operations. Another possibility is to use punched card equipment to rearrange data before or after computer manipulation.

(3) Magnetic tape. Data on magnetic tape while in the computer is primarily edited through programing. It may also be edited through the use of punched card equipment.

(4) Printers. Again, data edit operations are usually performed in the computer through programing. However, some printers have limited edit capabilities.

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36. PRINCIPLES OF COMPUTER OUTPUT FORMAT. The value of the computer, like the value of any machine, is determined by what it can produce. Since all computers produce information, the basic means of evaluating computer output comes from looking at its format. Basically, the format of computer output depends upon the specific type of output device used by the computer to prepare the output. As stated earlier, computer output can take the form of punched cards, punched paper tape, magnetic tape, or a printed medium. In any event, the goal of the whole computer operation is to obtain processed information that will answer our questions. In order to attain this goal in the most efficient manner, the information content of the printed output format should meet the following criteria:

a. Understandability. Output format must be understandable to the user. This requirement may be met by teaching the user to understand the machine output; however, there is a better method. The best method is to reduce the quantity of required output and have the computer dispense information in an easily recognizable and simplified form.

b. Relevancy. Output format must be relevant. If output format isn't relevant to the transaction, the content of the computer output should be revised. If, after closer examination, we find the present content is satisfactory but users are having difficulty, then the persons using the output should be given further training in its use. Occasionally, the relevancy of the output format can be improved by changing the type of input information. However, neither the processing nor the input should be changed until it is definitely determined that the changed output will meet the needs of the users.

c. Usability. Output must be in a usable format. The information has to be in a form that is easily assimilated and used. The primary remedy for a poor and unusable format is to improve the program or the instructions to the computer. Headings and columns can be rearranged, more blank space can be allowed, or size or type of print may be varied. Further, by using various devices, graphic information can be recorded on the output medium.

d. Completeness. Output information must be complete. If important items of information are missing from the output medium, a determination should first be made as to whether this information is or can be supplied by sources outside the computer. If not, the computer input must then be revised to provide for this additional output information.

37. OTHER INPUT AND OUTPUT DEVICES. The following input and output devices are used when a small volume of input or output data is desired. They are not designed for main volume input or output.

a. Console. On some systems, we can enter data or instructions into the computer by manually setting dials or buttons on the computer's console itself. The console is used to start a computer through a program, to correct errors, or to enter minor instructions or alterations in programs. By controlling the step-by-step progress of the computer, we can read the contents of certain components of the computer by means of the lights on the console. In this way we can monitor our program progress and results. However, we must remember that the console is not designed for main volume input and output.

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b. Console typewriter. Most computers are equipped with a modified typewriter on the console. This typewriter may be used to put data or instructions in the computer. Usually, the typewriter is not used for volume input because it is limited to the speed of the typist. Instead, it is used to introduce small amounts of data or corrections of data already in the computer. Insofar as output is concerned, the console typewriter is used only for exception-type information, such as printing out the contents of a register at the end of a certain program or for testing programs. In doing this, the computer is stopped at a particular program step and the console typewriter prints that program step.

c. Inquiry station. A device which is an extension of the computer console is known as an inquiry station. This keyboard device permits a fast, direct means of communication between a computer and a location geographically separated from the computer room. These inquiry stations may be as much as 50 feet to 2,000 miles away from the central computer. They could be linked together to form the entire inquiry system network.

(1) This inquiry station network is an inherent part of a real-time system. A real-time automatic data processing system is one in which a request for service and data to be processed may be entered at any time selected by the requester. The data must be processed and results transmitted to the requester in time to have some effect upon the events that caused the initial request.

(2) The most popular example of a real-time system is the airline ticket reservation system. The ticket agent has a desk set that he can use to query the central computer memory as to the availability of a seat on a particular flight and then to notify the computer that he has sold the seat. A response time of a few seconds for a nationwide system is typical.

(3) The IBM system 360/40 (fig 41) incorporates many of the input and output devices that we have just discussed.

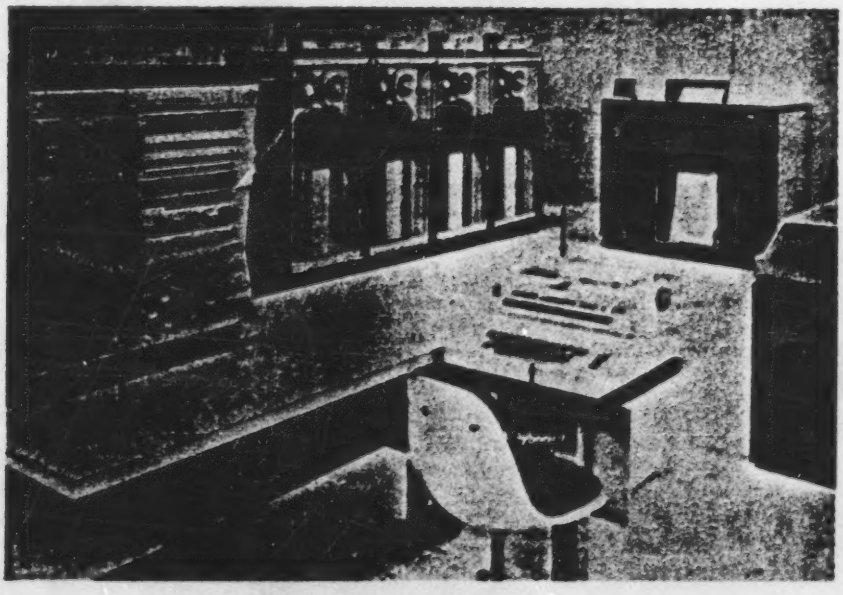

Figure 41. IBM system 360/40.

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APPENDIX I

REFERENCES

USAAGS MEMO 90-1	Introduction to Data Processing	Aug 71
USAAGS MEMO 90-3	Introduction to Automatic Data Processing Equipment	Aug 71
USAAGS MEMO 91-1	Machine Language	Aug 71
USAAGS MEMO 91-2	Input and Output Media and Devices	Aug 71
USAAGS MEMO 91-3	Storage	Aug 71
USAAGS MEMO 91-4	Central Processing Unit	Aug 71
USAAGS MEMO 214-1	Basic Automatic Data Processing	Aug 70

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APPENDIX II

COMPUTER ARITHMETIC

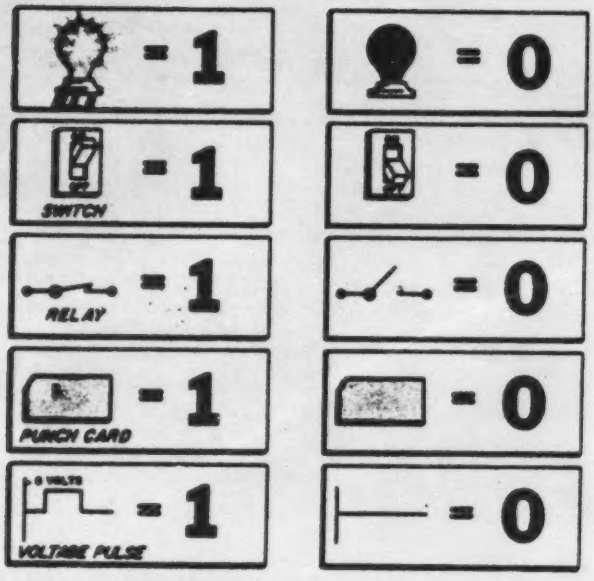

Figure 1. Binary representation.

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1. Just as different languages can express the same meaning, different numbering systems can express the same quantities. To understand the numbering system adaptable to electronic computers, it is beneficial to review the familiar decimal system.

no answer required

2. Each numbering system is identifiable by its base (or radix), which indicates the number of digits used in the system. The decimal system, with a base of ten, uses _____ different digits. The digits of the decimal system are 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. The highest number represented by a single digit is one less than the _____

10, base

3. A peculiarity of a positional numbering system is the manner in which we record the digits. The number 10 is quite different in value than 01 although the same digits are used. The difference in value is determined by the _____ of the digits in the whole number.

position

4. The value of each position in a multidigit number represents a specific power of the base. This is characteristic of all positional numbering systems. In the decimal system, the positions to the left or right of the decimal point increase or decrease in value by powers of _____

10

5. The powers of ten are : $10^0 = 1$, $10^1 = 10$, $10^2 = 100$, $10^3 = 1000$, etc. We commonly call these positions of the decimal system units, tens, hundreds, thousands, etc. Expressed as a power of ten, 10,000 would be _____.

10^4

6. For clarity and comparison, a simple graph illustrating positional value in powers of the base ten and the literal description may be useful.

thousands	hundreds	tens	units
10^3 or 1000	10^2 or 100	10^1 or 10	10^0 or 1

Record the decimal numbers 5347 and 3000 in the above graph, each digit in its proper value position.

thousands	hundreds	tens	units
10^3 or 1000	10^2 or 100	10^1 or 10	10^0 or 1
5	3	4	7
3	0	0	0

7. Each digit of a multidigit number can be expressed as that number times the power of the base. Complete this example:

4 9 6 8

( ) (9x) (6 x 10^1) (8 x 10^0)

The sum of these numbers is the original multidigit number.

4 9 6 8

(4 x 10^3) (9 x 10^2) (6 x 10^1) (8 x 10^0)

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22. Binary numbers may be easily converted to decimal numbers by the positional notation method. Each position is assigned its value. The values are then added together. It is convenient to begin with the least significant digit, as illustrated in problem 1.

1. Convert 1101 to a decimal number by completing this problem:

$(1 \times 2^3) =$
$(1 \times 2^2) =$
$(0 \times 2^1) =$
Least significant digit ⟶ $(1 \times 2^0) =$ _____

2. Convert 111011 to a decimal number.

$(1 \times 2^3) = 8$
$(1 \times 2^2) = 4$
$(0 \times 2^1) = 0$
$(1 \times 2^0) = 1$
13

$(1 \times 2^5) = 32$
$(1 \times 2^4) = 16$
$(1 \times 2^3) = 8$
$(0 \times 2^2) = 0$
$(1 \times 2^1) = 2$
$(1 \times 2^0) = 1$
59

---

23. Convert the following binary numbers to their decimal equivalents.

10101 = _____
110011 = _____
101100110 = _____

10101 = 21, 110011 = 51, 101100110 = 358

---

24. As further practice in binary to decimal conversion, list the decimal equivalents of the following:

1010 = _____	0100 = _____
1001 = _____	0001 = _____
0101 = _____	0011 = _____
0010 = _____	0110 = _____
0111 = _____	1000 = _____

1010 = 10	0100 = 4
1001 = 9	0001 = 1
0101 = 5	0011 = 3
0010 = 2	0110 = 6
0111 = 7	1000 = 8

---

25. The most commonly used method of decimal to binary conversion is the remainder method. The decimal number is divided by two and that quotient and all succeeding quotients are in turn divided by two. The remainders of each division must be 1 or 0 and these make up the bits of the binary number with the final remainder the most significant digit. Using the decimal 13, the remainder method is illustrated below.

6 3 1 0
$(2/\overline{13}\ R = 1)$ $(2/\overline{6}\ R = 0)$ $(2/\overline{3}\ R = 1)$ $(2/\overline{1}\ R = 1)$ = 1101 binary

---

no answer required

---

26. In the previous example, decimal 13 was converted to binary 1101. To prove this answer, convert binary 1101 to decimal by using powers of two.

_____ + _____ + _____ + _____ = 13

$$\underset{8}{(1\times 2^3)} + \underset{4}{(1\times 2^2)} + \underset{0}{(0\times 2^1)} + \underset{1}{(1\times 2^0)} = 13$$

27. When using the remainder method, remember that the last remainder is the most significant digit. The example below demonstrates this rule and converts the decimal number 30 to a binary number:

	0	R = 1 ← Most significant digit
	2/1	R = 1
	2/3	R = 1
	2/7	R = 1
	2/15	R = 0
Begin here →	2/30	

The binary number is: _____

11110

28. Convert the following decimal numbers to binary numbers using the remainder method.

11 = _____
51 = _____
358 = _____

11 = 1011		51 = 110011		358 = 101100110	
0	R = 1	0	R = 1	0	R = 1
2/1	R = 0	2/1	R = 1	2/1	R = 0
2/2	R = 1	2/3	R = 0	2/2	R = 1
2/5	R = 1	2/6	R = 0	2/5	R = 1
2/11		2/12	R = 1	2/11	R = 0
		2/25	R = 1	2/22	R = 0
		2/51		2/44	R = 1
				2/89	R = 1
				2/179	R = 0
				2/358	

29.

0	R = 1		
2/1	R = 1		
2/3	R = 1	A	The method used in this example converts a _____ number to a _____ number.
2/7	R = 0		
2/14	R = 0		
2/28	R = 0		
2/56			
$1\times 2^3 = 8$			
$1\times 2^2 = 4$		B	This method converts a _____ number to a _____ number.
$0\times 2^1 = 0$			
$1\times 2^0 = 1$			
13			

A. decimal / binary

B. binary / decimal

30. The basic operation performed in the arithmetic unit of the central processor is calculation _____. Consequently any numbering system compatible with automatic data processing must have the quality to permit _____.

calculation

8. Write this decimal number using powers of the base.

6 5 2 1

_____ + _____ + _____ + _____

The rightmost digit (1) has the smallest value (1×10^0), so is the least significant digit. The leftmost digit (____) has the highest value (_____). It is the _____ significant digit.

6 5 2 1

$(6 \times 10^3) + (5 \times 10^2) + (2 \times 10^1) + (1 \times 10^0)$

6, (6×10^3), most significant digit.

9. One rule to be remembered which is applicable to any positional numbering system; the base (or radix) to the zero power equals one (1)

$2^0 = 1,\ 8^0 = 1, 10^0 = 1,\ 16^0 = 1.$

no answer required

10. Complexity of electronic circuitry necessary for utilizing the decimal system has resulted in a simpler two digit system for computer use. This system, having a base of two, must use the digits _____ and _____

0, 1

11. Just as the decimal system can express any quantity with _____ digits, the binary system can express any quantity with the digits 0 and 1.

ten

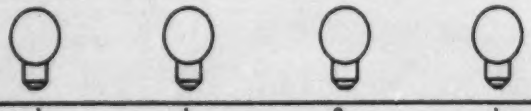
12. This two value system, using 0 and 1 and called the binary numbering system, lends itself to computer circuitry. A common example used in explaining this two value concept is the light bulb. The light bulb can only be in one of two states, _____ or _____

on, off

13. If we represent the off state of the light bulb by the binary zero (0), it is readily apparent the on state can be represented by the binary _____. A string of lights in a systematic on and off configuration could represent any _____ number.

1, binary

14. A binary number is represented by a series of 1's and 0's called "bits" (a contraction of "binary digits"). Using light bulbs to represent the binary number 1101, which bulbs would be on and which ones would be off?



1 ON 1 ON 0 OFF 1 ON

15. The computer, of course, does not employ light bulbs, but does operate on the same on-off principle. Transistors are either conducting or nonconducting; magnetic tape, discs, and drums are magnetized or not magnetized, and cores are magnetized in one of two polarities. Punch cards are either _____ or _____.

punched, not punched

16. The bistable or two state devices listed in the previous statement are adaptable to the _____ numbering system. Since the position of the digits 0 and 1 determines their value, this system, like the decimal system is also a _____ numbering system.

binary, positional

17. Since binary is a numbering system with a base of two, positional value of digits increases or decreases by powers of _____.

two

18. Powers of ten are 10^0, 10^1, 10^2, 10^3, etc., and represent values 1, 10, 100, 1000. Using the powers of two, what are the decimal values of 2^0, 2^1, 2^2, 2^3, 2^4?

2^0 = _____ 2^1 = _____ 2^2 = _____ 2^3 = _____ 2^4 = _____

$2^0 = 1$ $2^1 = 2$ $2^2 = 4$ $2^3 = 8$ $2^4 = 16$

19. Illustrated in a simple graph as used with the decimal system, the powers of two and positional values are easily determined.

Decimal Value Powers of 2	Sixteen 2^4	Eight 2^3	Four 2^2	Two 2^1	Units 2^0

Record the binary numbers 1101 and 10001 in the graph and determine the decimal equivalent. 1101 = _____ 10001 = _____

sixteen 2^4	eight 2^3	four 2^2	two 2^1	units 2^0
	1	1	0	1
1	0	0	0	1

1101 = 8 + 4 + 0 + 1 = 13, 10001 = 16 + 0 + 0 + 0 + 1 = 17

20. Each digit of a multidigit binary number can be expressed as that number times its power of the base 2. Example: 1011 is $(1 \times 2^3) + (0 \times 2^2) + (1 \times 2^1) + (1 \times 2^0)$. The sum of the individual digits is the decimal equivalent. Write the binary number 1111 using powers of the base and determine the decimal value.

_____ + _____ + _____ + _____ = _____

$(1 \times 2^3) + (1 \times 2^2) + (1 \times 2^1) + (1 \times 2^0) = 15$

21. Binary 0 is equal to decimal 0 and binary one by itself is equal to decimal 1. Since binary is a system using a base of two and only digits 0 and 1, any quantity over one (1) requires a multidigit binary number. Decimal 2 written in binary is _____. $(1 \times 2^1) + (0 \times 2^0)$

10

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31. Binary arithmetic follows the same general rules as decimal arithmetic except that base two tables are used instead of base ten tables. The following are the four basic rules of binary addition: $0 + 0 = 0$, $0 + 1 = 1$, $1 + 0 = 1$, $1 + 1 = 0$ plus a carry of 1.

Example: Add 1011 + 1010

```
 c c          ("c" indicates a carry)
 1011 =
 1010 =
10101 =       Convert the binary numbers to decimal, add and check the result.
```

```
 1011 = 11
 1010 = 10
10101 = 21
```

32. Whenever a column generates more than one carry, a "c" is inserted in the next column for each carry. Each "c" is treated as a 1 in its column.

```
          c  c
         cccccc
          10111 = 23          Solve:   10110        1011
Example:  10011 = 19                     1010         111
          11010 = 26                  111011        1011
         1000100 = 68
```

```
 cccc
  10110
   1010
 111011
1011011
```

```
   c
 cccc
  1011
   111
  1011
 11101
```

33. As practice and to check accuracy, solve the following binary additions, then convert to decimal and verify results.

```
 1111      1101      1011
 1111      1110        11
```

```
 1111 = 15      1101 = 13      1011 = 11
 1111 = 15      1110 = 14        11 =  3
11110 = 30     11011 = 27      1110 = 14
```

34. To facilitate computer subtraction, a method involving COMPLEMENTATION and END-AROUND CARRY is used.

```
Problem:    Minuend     1101011     1101011     Minuend
            Subtrahend  −1011110    +0100001     (Complemented Subtrahend)
                                    ①0001100
                                           ↘1
                                    0001101 =
```

Complementation and end-around carry method.

Convert the problem to decimal, perform the subtraction and compare your answer to the complementation and end-around carry answer.

```
 1101011 = 107
−1011110 =  94
           13 = 1101
```

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35. The first rule in solving subtraction by addition—THE COMPLEMENT OF A DIGIT IS EQUAL TO ONE LESS THAN THE RADIX, MINUS THAT DIGIT. Following this rule, the decimal system uses the 9's complement and binary uses the 1's complement. Both 9 and 1 are one less than the base 10 and 2, respectively.

Example: The 9's complement of 6 is: 9 minus 6, or 3.
The 1's complement of 0 is: 1 minus 0, or 1.

What is the 9's complement of 632? (Complement each digit) _____
What is the 1's complement of 1100? _____.

367,0011

36. Complementing the subtrahend of a binary subtraction problem merely involves changing all ones to zeroes and all zeroes to ones. The 1's complement of 0011101 is 1100010.

Complement the following:

10010 = _____
00100 = _____
11111 = _____

It is that simple.

01101
11011
00000

37. minuend A. 10110
subtrahend B. 110

In complementing a subtrahend, leading zeros are always implied. In this example, the subtrahend is written 00110. The complement of B is _____.

A. 10110 A. 10110
B. −00110 B. −11001 ← Complement of B

38. Complement the subtrahend of the binary subtraction problems below. Remember that leading zeros are implied.

101111 1110111
100101 100010
ans. _____ ans. _____

011010 1011101

39. After complementing the subtrahend, the next step is adding the complemented number to the minuend. Complement and add in the following problems.

101010 = 101010 111011 = 111011
−10101 = _____ −100011 = _____

ccc ccc
101010 111011
101010 011100
1010100 1010111

40. The previous problems were:

101010 101010 111011 111011
−10101 +101010 −100011 +011100
1010100 1010111

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It is apparent these answers are not correct. In both cases, the answer contains more digits than the minuend. One additional step is required.

---

no answer required

---

41. The last step is called "end-around carry."

101010	101010	111011	111011
−10101	101010	−100011	011100
	①010100		①010111
	→ 1		→ 1
	10101		11000

Rule for end-around carry: THE 1 IN THE HIGH ORDER POSITION (MOST SIGNIFICANT DIGIT) IS ADDED TO THE 2^0 POSITION (LEAST SIGNIFICANT DIGIT). CONVERT THE PROBLEMS TO DECIMALS AND CHECK THESE ANSWERS.

101010 = 42	111011 = 59
−010101 = 21	−100011 = 35
10101 = 21	11000 = 24

---

42. Using the complementation and end-around carry method solve this problem.
SUBTRACT B FROM A. STEP #1 COMPLEMENT B. STEP #2 ADD A, AND B COMPLEMENT.

A. 101011	A. 101011	A. 101011
B. 11101	B. _____	B. _____

ANS. _____ (STEP #3 NEXT FRAME)

STEP #1	101011	STEP #2	101011
	100010		100010
			1001101

---

43. Continuing with the previous problem 101011 minus 011101.

STEP #1 COMPLEMENTING		STEP #2 ADD	STEP #3 PERFORM END-AROUND CARRY AND ADD
A. 101011	A. 101011	A. 101011	①001101
−11101	100010	100010	→ 1
		1001101	

Answer ⟶

Convert the original problem to decimal and check your answer.

A. 101011 = 43
B. 011101 = 29
14 = 14

---

44. For practice and understanding, solve the following subtraction using complementation and end-around carry.

1101011	11100
−1011110	−101
ANS. _____	ANS. _____

1101011	11100
0100001	11010
①0001100	①10110
→ 1	→ 1
1101	10111

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45. Often a binary number may contain so many bits it becomes unwieldy and extremely difficult to communicate other than in the computer. A variation of binary is used to permit communication of binary values without long series of 1's and 0's. This system is called Binary-Coded Decimal.

no answer required

46. Compare these two examples:

Binary	Binary-Coded Decimal
25 is shown as 11001	25 is shown as 0010 0101
16 is shown as 10000	16 is shown as 0001 0110

What is the difference between these two systems?

Binary treats the number as a whole. Binary-Coded Decimal uses four binary positions to represent each digit of the decimal number.

47. While the computer works most efficiently in binary, _____ _____ _____ provides a system that is easier for humans to interpret.

Binary-Coded Decimal

48. Convert the following numbers to binary and Binary-Coded Decimal (BCD).

	Binary	BCD
26	_____	_____ _____
63	_____	_____ _____
125	_____	_____ _____ _____
40	_____	_____ _____

	Binary	BCD
26	11010	0010 0110
63	111111	0110 0011
125	1111101	0001 0010 0101
40	101000	0100 0000

49. Another method of making otherwise unwieldy binary numbers easier to work with is in the use of another number system. The octal numbering system uses the digits 0, 1, 2, 3, 4, 5, 6, and 7.

no answer required

50. Each position within an octal number represents a specific power of the radix 8. What are the specific values (decimal) of the following powers of 8?

8^0 = _____ 8^1 = _____ 8^2 = _____ 8^3 = _____

$8^0 = 1$, $8^1 = 8$, $8^2 = 64$, $8^3 = 512$

51. Dealing with more than one numbering system can lead to confusion unless care is exercised. As examples, 236 could be either a decimal or octal number and 101 could be decimal, octal, or binary. If there is any room for doubt a subscript must be appended to the number.

236_8 is an _____ number. 101_2 is a _____ number. 236_{10} is a _____ number.

236_8 octal 101_2 binary, 236_{10} decimal

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52. In octal to decimal conversion, as with binary to decimal, each position is assigned its value of the power of the base and the values are added together. Thus, 356_8 is equal to:

$3 \times 8^2 =$
$5 \times 8^1 =$
$6 \times 8^0 =$
TOTAL = _____

$3 \times 8^2 = 192$
$5 \times 8^1 = 40$
$6 \times 8^0 = 6$
TOTAL = 238_{10}

53. Using the powers of the base 8, convert the following octal numbers to their decimal equivalent.

$6540_8 =$

$6 \times 8^3 = 3072$
$5 \times 8^2 = 320$
$4 \times 8^1 = 32$
$0 \times 8^0 = 0$
3424_{10}

$11_8 =$

$1 \times 8^1 = 8$
$1 \times 8^0 = 1$
9_{10}

$235_8 =$

$2 \times 8^2 = 128$
$3 \times 8^1 = 24$
$5 \times 8^0 = 5$
157_{10}

$77_8 =$

$7 \times 8^1 = 56$
$7 \times 8^0 = 7$
63_{10}

54. For decimal to octal conversion, the easiest approach is the remainder method explained in decimal to binary conversion. A division of 8 is used instead of 2. Remember, the last remainder is the most significant digit of the total number.

Convert 77_{10} to its octal equivalent. ANS. _____

115_8

$8/\overline{77}$ R = 5
$8/\overline{9}$ R = 1
$8/\overline{1}$ R = 1
0 R = 1

55. Convert the following decimal numbers to their octal equivalent.

$8_{10} =$ $88_{10} =$ $786_{10} =$ $888_{10} =$

$8_{10} = 10_8$ $88_{10} = 130_8$ $786_{10} = 1422_8$ $888_{10} = 1570_8$

56. Explain briefly in your own words why 2 is not a valid binary number and 9 is not a valid octal number. _____

The base or radix of a numbering system indicates the number of digits used in that system. The highest number represented by a single digit in any system is one less than the base. Binary has a base of 2 and the highest single digit is 1. Two does not exist in this system. Octal has a base of 8 and the highest single digit is 7. Nine does not exist in the octal system.

57. Define base or radix and positional numbering systems. _____

Base or radix indicates the number of digits in the system. The power of the base is denoted by the position of the digit.

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58. It was mentioned that octal provides a shorthand method for dealing with binary numbers. To illustrate, first represent each of the 8 octal numbers as three bit numbers. If necessary, add zeros to the left to make three bit numbers.

0 = 000 2 = _____ 4 = _____ 6 = _____
1 = 001 3 = _____ 5 = _____ 7 = _____

0 = 000, 1 = 001, 2 = 010, 3 = 011, 4 = 100, 5 = 101, 6 = 110, 7 = 111

59. Any binary number may be converted to octal by grouping the bits in 3's starting at the right-most bit and then converting each group into its octal equivalent. Example: $100/111 = 47_8$

To prove, convert the binary number 100111 and the octal number 47 to their decimal equivalents.

100111_2 = _____ = _____

32	16	8	4	2	1		
1	0	0	1	1	1	=	32 + 4 + 2 + 1 = 39_{10}

$100111 = 39_{10}$

64	8	1		
	4	7	=	32 + 7 = 39_{10}

$47_8 = 39_{10}$

60. Convert the following binary numbers to octal numbers and the resultant octal numbers to their decimal equivalent.

	OCTAL	DECIMAL
101110 =	_____	_____
1001101 =	_____	_____
1111111111 =	_____	_____

101/110 = 56_8 = 46_{10}, 1/001/101 = 115_8 = 77_{10}, 1/111/111/111 = 1777_8 = 1023_{10}

61. Convert the following decimal numbers to binary using the remainder method and then convert the binary results to octal numbers.

	BINARY	OCTAL
511 =	_____	_____
426 =	_____	_____
112 =	_____	_____

511 = 111/111/111 = 777_8, 426 = 110/101/010 = 652_8, 112 = 1/110/000 = 160_8

62. The shorthand octal method of converting binary numbers is not by accident or coincidence. In the graph below you can readily see the interrelationship of each higher power of 8 to each third higher power of 2.

8^4			8^3			8^2			8^1			8^0
2^{12}	2^{11}	2^{10}	2^9	2^8	2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0
4096			512			64			8			1

no answer required

63. The numbering systems discussed have the additional capability of representing data other than digits.

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A common alphanumeric code allows for 64 different six bit combinations. Most commonly, they are: (1) the 26 alphabetic characters, (2) the 10 decimal digits, and (3) 20 special characters. Each is expressed as some combination of _____ bits.

---

six

---

64. The alphanumeric code represents decimal digits with six bits. To represent digits, the first two bits (most significant) will always be 0 (zero). To assure a six bit configuration, zeros may have to precede the binary code. Example: One (1) is 00 0001. Record the alphanumeric code for all 10 decimal digits.

0. _____ 2. _____ 4. _____ 6. _____ 8. _____
1. _____ 3. _____ 5. _____ 7. _____ 9. _____

---

0 = 00 0000 2 = 00 0010 4 = 00 0100 6 = 00 0110 8 = 00 1000
1 = 00 0001 3 = 00 0011 5 = 00 0101 7 = 00 0111 9 = 00 1001

---

65. Any multidigit decimal number is encoded in alphanumerics by using a six bit configuration for each digit. Example: 27 equals 000010, 000111. Supply the decimal equivalent of the following alphanumeric codes.

00 0101 00 0111 = _____ 00 0100 00 0001 = _____
00 1001 00 1000 = _____ 00 0010 00 0011 = _____

---

00 0101 00 0111 = 57 00 0100 00 0001 = 41
00 1001 00 1000 = 98 00 0010 00 0011 = 23

---

66. Encoding of the alphabet in alphanumeric form is accomplished by dividing the alphabet into three groups and prefacing each group with a different pair of leading bits. A through I is prefaced by (11), J through R prefaced by (10), and S through Z prefaced by (01). Within the first two groups, each letter is designated by the four bit representation of its position within the group. C, the third letter in the group prefaced by 11, is represented as 110011.

---

no answer required

---

67. Remembering that A through I is prefaced by 11 and J through R is prefaced by 10, encode these 18 letters of the alphabet in alphanumeric code.

A = E = J = N =
B = F = K = O =
C = G = L = P =
D = H = M = Q =
I = R =

A = 110001 E = 110101 J = 100001 N = 100101
B = 110010 F = 110110 K = 100010 O = 100110
C = 110011 G = 110111 I = 111001 L = 100011 P = 100111 R = 101001
D = 110100 H = 111000 M = 100100 Q = 101000

---

68. The S through Z group contains only 8 letters. Each letter within this group is represented by a binary representation of a number one greater than its position within the group and preceded by 01. Complete the encoding for the remainder of this group.

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S = 010010 T =	U = V =	W = X =	Y = Z =

S = 010010	U = 010100	W = 010110	Y = 011000
T = 010011	V = 010101	X = 010111	Z = 011001

69. Rote memory of the entire alphanumeric code would be extremely difficult. Remembering the alphabetic groupings and the preceding two bits will permit encoding. 00 precedes decimal digits, 11 precedes A–I, 10 precedes J–R, and 01 precedes S–Z. Encoding special characters is recommended by use of the code chart.

no answer required

SUMMARY

Numbering Systems

1. The numbering system utilized by most computer circuits has a binary base and is characterized by 1's and 0's. Circuits are restricted to recognition of a:
   Condition present (1)—punched hole, electrical pulse, ON, etc.
   Condition absent (0)—hole not punched, no electrical pulse, OFF, etc.
2. Octal or decimal numbers are used as a convenience for the programer in expressing binary numbers.
3. The amount (value) of any given quantity is identical regardless of whether is is expressed in decimal, octal, or binary.

   For example: 4095_{10} is identical to 7777_8 which is identical to 111111111111_2.

Alphanumeric Code

1. Six binary digits are used to designate digits, letters, and special characters in alphanumeric classification.
2. The leftmost (high order) two digits specify a group as digits or letters.
3. The rightmost (low order) four digits specify the position within a group with two exceptions:
   a. The letter group S–Z where the low order four digits equal one greater than the position in the group.
   b. A decimal value of the low order four binary digits that is greater than nine designates a special character.

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APPENDIX III

SOLUTIONS TO PRACTICAL EXERCISE

Practical Exercise Number 1.

	32	16	8	4	2	1
6 =				1	1	0
7 =				1	1	1
9 =			1	0	0	1
10 =			1	0	1	0
11 =			1	0	1	1
20 =		1	0	1	0	0
23 =		1	0	1	1	1
32 =	1	0	0	0	0	0
40 =	1	0	1	0	0	0
45 =	1	0	1	1	0	1
50 =	1	1	0	0	1	0

Practical Exercise Number 2.

	1024	512	256	128	64	32	16	8	4	2	1
25 =							1	1	0	0	1
50 =						1	1	0	0	1	0
100 =					1	1	0	0	1	0	0
500 =			1	1	1	1	1	0	1	0	0
1,200 =	1	0	0	1	0	1	1	0	0	0	0
1,967 =	1	1	1	1	0	1	0	1	1	1	1

Practical Exercise Number 3.

	8 4 2 1	8 4 2 1	8 4 2 1	8 4 2 1
33 =			0 0 1 1	0 0 1 1
76 =			0 1 1 1	0 1 1 0
100 =		0 0 0 1	0 0 0 0	0 0 0 0
295 =		0 0 1 0	1 0 0 1	0 1 0 1
471 =		0 1 0 0	0 1 1 1	0 0 0 1
1,560 =	0 0 0 1	0 1 0 1	0 1 1 0	0 0 0 0
1,967 =	0 0 0 1	1 0 0 1	0 1 1 0	0 1 1 1

ARMY—AFS, MD—547-M

CORRESPONDENCE COURSES of the U.S. ARMY ORDNANCE CENTER AND SCHOOL

VERSION 1

EXAMINATION

Ordnance Subcourse No 905	Automatic Data Processing
Credit Hours	One
Objective	To test your knowledge of all material studied in this subcourse.
Texts	All supplemental pamphlets used in this subcourse.
Materials Required	None
Suggestions	Review all lessons studied in this subcourse.

(Do not send these pages in — use the answer sheet provided for recording and mailing your solution.)

Requirement - 35 Questions - Weight 100 — All items are weighted equally.

MULTIPLE CHOICE

(See instructions on answer sheet provided)

1. Which component of the card punch is an output device?

   a. Card stacker
   b. Card hopper
   c. Punching station
   d. Reading station

2. How is access time used in computer operations?

   a. As the primary factor in the selection of automatic data processing equipment
   b. As the primary factor in comparing one computer with another
   c. To determine the length of time needed to solve a data processing problem
   d. To indicate only the speed of the computer

4-1

3. Which element of a card punch controls automatic skipping, duplicating, and shifting from numeric to alphabetic punching?

   a. Punching station
   b. Program unit
   c. Reading station
   d. Reading board

4. The first practical computer, although it did not have vacuum tubes, was the

   a. loom built by Jacquard.
   b. Hollerith card processor.
   c. Mark I.
   d. ENIAC.

5. Which punches must be used to encode the letter "I" in an 80-column punched card?

   a. 12-zone and 9-numeric
   b. 0-zone and 1-numeric
   c. 0-zone and 3-numeric
   d. 11-zone and 4-numeric

6. Which features describe magnetic core storage of a computer's central processing unit?

   a. Destructive read-in, destructive read-out, and volatile
   b. Volatile, nondestructive read-in, and destructive read-out
   c. Nondestructive read-in, nonvolatile, and nondestructive read-out
   d. Destructive read-in, nondrestructive read-out, and nonvolatile

7. What is the third step in the machine accounting principle?

   a. Summarizing
   b. Sorting
   c. Interpreting
   d. Merging

8. Which generation of computers is characterized by monolithic integrated circuitry?

   a. First
   b. Second
   c. Third
   d. Fourth

9. Which factor is a disadvantage in the use of punched cards for processing data?

   a. Errors are difficult to detect and correct
   b. Cards are slow when used for computer input or output
   c. Cards cannot be sorted or corrected manually
   d. Formats are difficult to design for various applications

10. When a storage location is designated by a numerical address, it is called

    a. nonaddressable storage.
    b. symbolic addressing.
    c. relative addressing.
    d. absolute addressing.

11. Which punched card machine(s) would you use to arrange two files of cards into a single file according to a predetermined pattern?

    a. Sorter
    b. Collator
    c. Collator and interpreter
    d. Sorter and collator

12. Which computer application consists of a small amount of input, a large amount of computation, and a small amount of output?

    a. Business
    b. Banking
    c. Scientific
    d. Supply

13. Which bulk storage device economically extends online direct access storage capabilities to a volume of data beyond that of other storage devices?

    a. Data cell drive
    b. Card access random memory
    c. Magnetic drums
    d. Magnetic disks

14. Which punched card operations may be performed at the same time?

    a. Sorting and punching
    b. Punching and accumulating
    c. Merging and punching
    d. Matching and merging

15. Which basic data processing operation does an interpreter perform?

    a. Checking
    b. Reporting
    c. Recording
    d. Classifying

16. Which punched paper channels are used most frequently as input and output media in AMPS operations?

    a. Five- and seven-channel tapes
    b. Five- and eight-channel tapes
    c. Seven- and eight-channel tapes
    d. Six- and seven-channel tapes

17. Which type of cards are punched from information previously recorded on other documents?

    a. Dual
    b. Output
    c. Transcript
    d. Mark-sense

18. How many binary digits are required in binary-coded decimal to represent one decimal digit?

    a. 4
    b. 3
    c. 2
    d. 1

19. Which alphabetic characters, composed of two punches, require a 12-zone punch and a numeric punch?

    a. TOG
    b. NOW
    c. GAD
    d. FOR

20. Which predetermined function is performed by collators?

    a. Summarizing
    b. Reporting
    c. Filing
    d. Writing

21. Which describes a volatile storage device?

    a. Data is erased from storage by reading out of storage
    b. Data stored is destroyed if the electric power supply is shut OFF
    c. Data is not erased from storage by the read-out process
    d. Data once stored is retained in storage until it is deliberately removed

22. Which item of punched card equipment is used for sequence checking of cards?

    a. Sorter
    b. Interpreter
    c. Calculator
    d. Collator

23. Which type of coding system is used in computers designed for scientific calculations?

    a. Straight binary representation
    b. Binary-coded decimal
    c. Two-out-of-five code
    d. Excess three system

24. Which item of punched card equipment can perform the basic functions of a reproducing punch and calculator?

a. Interpreter
b. Transceiver
c. Accounting machine
d. Card processor

25. The first digital device employing mechanical means rather than hand operation in arithmetic process was

a. the abacus.
b. Pascal's calculator.
c. Babbage's analytical engine.
d. Napier's bones.

26. The control element of a computer system is responsible for

a. directing the computer in performing its operations.
b. doing all the mathematical work in the system.
c. holding information required for computations.
d. getting both data and instructions into the system.

27. Which punch on an 80-column punched card serves as both a zone punch and a numeric punch?

a. 12 punch
b. 11 punch
c. 0 punch
d. X punch

28. What is the name of a punched card that records information by means of marks made on the card with an electrographic pencil?

a. Penching card
b. Electronic card
c. Magnetic ink card
d. Mark-sense card

29. Which item of punched card equipment contains a component primarily used in computers?

a. Interpreter
b. Calculator
c. Accounting machine
d. Electronic statistical machine

30. The relatively slow speed of input and output devices in comparison with the fast speed of the computer is the basis for which problem?

    a. Compatibility of equipment
    b. Inadequate communication
    c. Electronic disparity
    d. Systems imbalance

31. Which factor is the most important consideration in determining a punched card's data sequence?

    a. The machines and/or programs to be used during processing
    b. The location of identical data in other cards with which the new one will be processed
    c. The sequence of data on the source document from which the card will be punched
    d. The manual operations in which the card will be used

32. Which component of an ADPS calculates and tests?

    a. Input unit
    b. Output unit
    c. Control unit
    d. Arithmetic and logic unit

33. Which function can be performed by a document originating machine?

    a. Selecting
    b. Matching
    c. Gang-punching
    d. Match-merging

34. What is the purpose of verifying in punched card operations?

    a. Check accuracy of original keypunching
    b. Write card content in zone area
    c. Report errors on a hard copy
    d. File cards which are incorrect

35. If a punched card contains multiple punching in one or more columns and the punches were not placed there intentionally, the card is

    a. multiple punched.
    b. off punched.
    c. controlled.
    d. laced.